Water Power

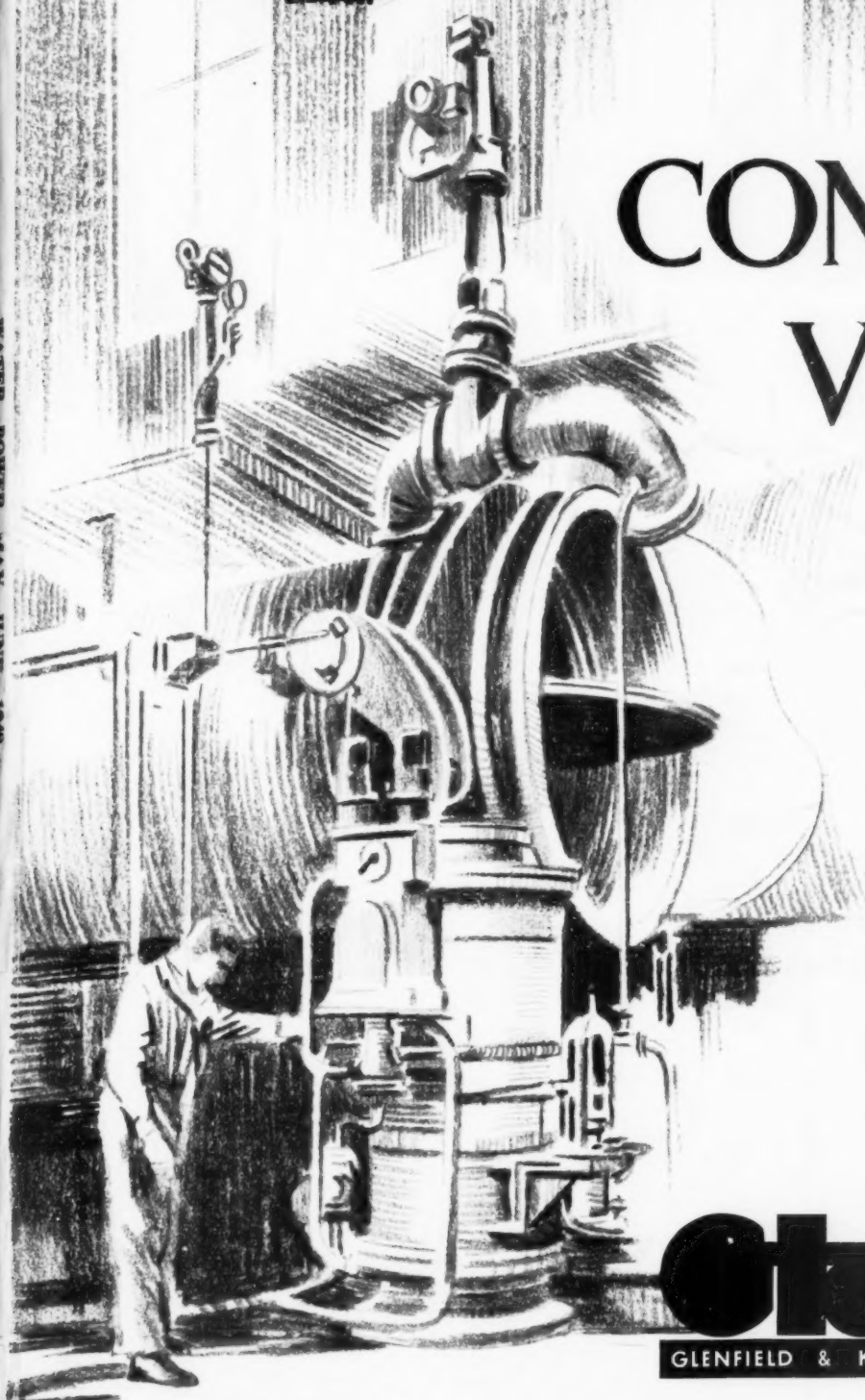
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

LIBRARY

MAY-JUNE 1949

CONTROL VALVES

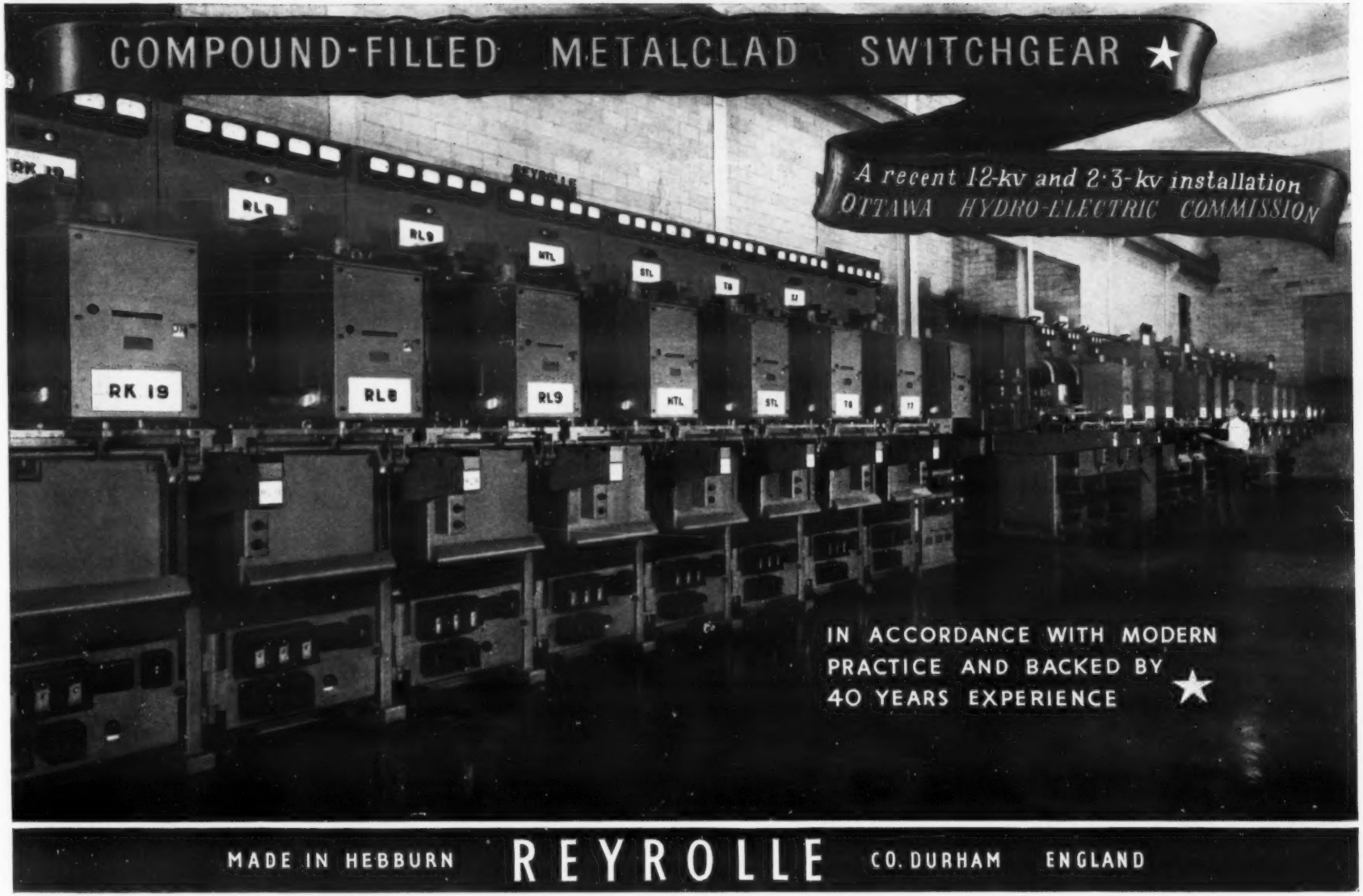
for HYDRO-ELECTRIC PIPELINES and DAMS

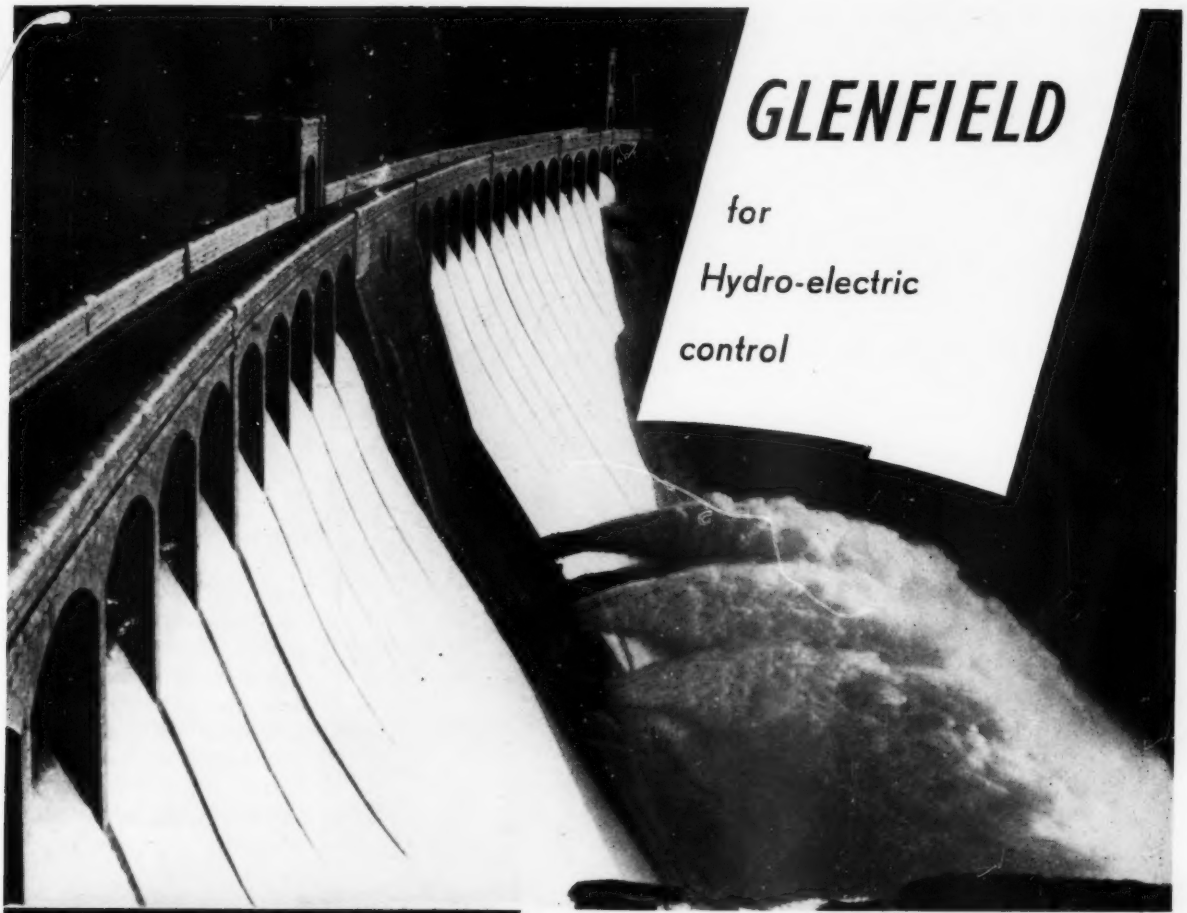


Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

WATER POWER MAY-JUNE 1949


COMPOUND-FILLED METALCLAD SWITCHGEAR ★
A recent 12-kv and 2·3-kv installation
OTTAWA HYDRO-ELECTRIC COMMISSION
RK 19
RL8
RL9
IN ACCORDANCE WITH MODERN
PRACTICE AND BACKED BY
40 YEARS EXPERIENCE ★
MADE IN HEBBURN
REYROLLE
CO. DURHAM ENGLAND



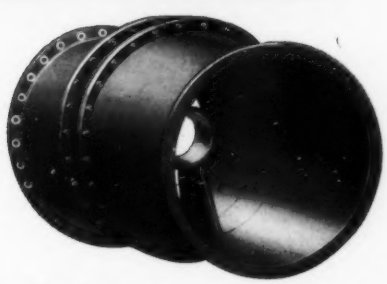
GLENFIELD

for

Hydro-electric

control

JET DISPERSERS



GLENFIELD JET DISPERSERS are in use throughout the world on points of free discharge.

On siphon spillways, scours and on compensation water outlets from dams and reservoirs, and washouts from pipelines.

To result in the harmless dissipation of the issuing jet, without vibration or erosion either of the disperser itself or of the area on which the discharge falls whether into river bed—tunnel—or ditch.

To render elaborate and costly protective works unnecessary.

The top illustration shows six jet dispersers on a siphon spillway each designed to discharge at the rate of 620 cubic feet of water per second to absorb in turn a total of 25,000 H.P. in the process.

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CALCUTTA OFFICE : Fairlie House, Fairlie Place, P.O. Box 2115.
Representatives in most countries

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Another difficult site

successfully dewatered

This contract involved the construction of an outfall culvert to the sea, in sand dunes, at a depth of 14ft. Permanent water level was just below the surface. By the use of Millars' Wellpoints, excavation was carried right down to the shore, the site being perfectly dry within a few feet of the sea.

by MILLARS'

WELLPOINT DEWATERING SYSTEM

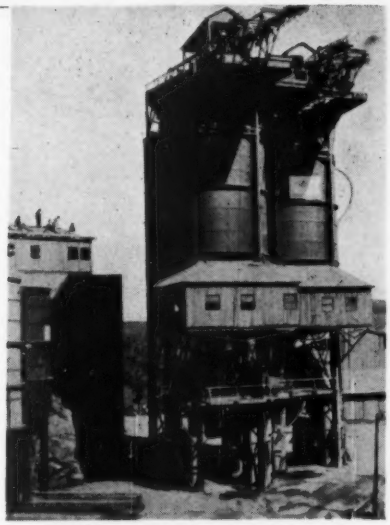
MILLARS' MACHINERY COMPANY LIMITED
THORLEY, BISHOP'S STORTFORD, HERTS.
WELLPOINT DEPARTMENT: *Cromford House, Cromford Court, Manchester 4. Phone Blackfriars 8814.*

33/543

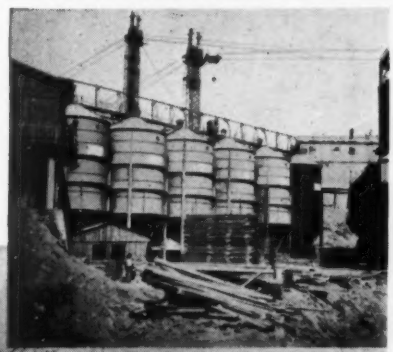
Castelo Do Bode Dam

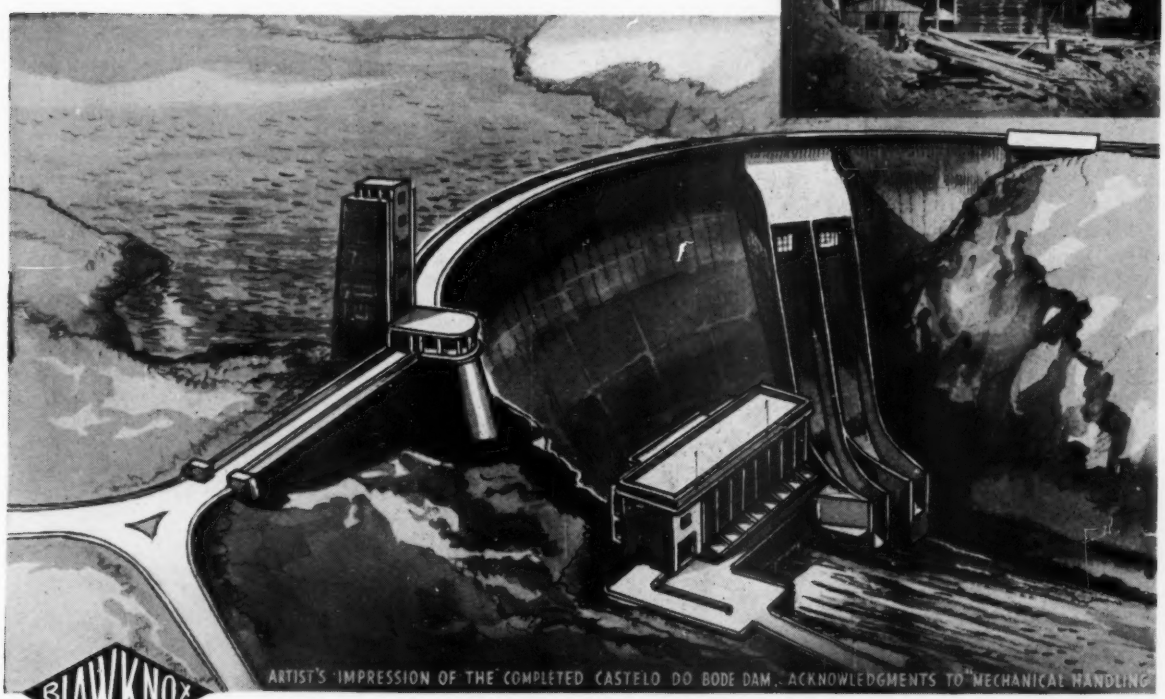
This great engineering project on the River Zezere is part of the Portuguese Government's plan to provide hydro-electric power to feed a grid system for the electrification of railways from Lisbon to Oporto and for industrial development of the Country. The Central Mixing Station was supplied and erected by Blaw Knox and this contribution to a great undertaking is symbolic of the high quality construction equipment and integrity of service offered to engineers in the word-wide effort to build more, build faster and build to last.

BATCHING, MIXING AND BULK CEMENT PLANT · MOTOMIXERS · CONCRETE SPREADERS AND FINISHERS · CONCRETE MIXERS · ROADFORMS · STEEL SHUTTERING · CONCRETE PUMPS · DEWATERING PLANT · EXCAVATORS EARTH MOVING EQUIPMENT



CENTRAL MIXING STATION AND BULK CEMENT STORAGE BINS





ARTIST'S IMPRESSION OF THE COMPLETED CASTELO DO BODE DAM. ACKNOWLEDGMENTS TO "MECHANICAL HANDLING"

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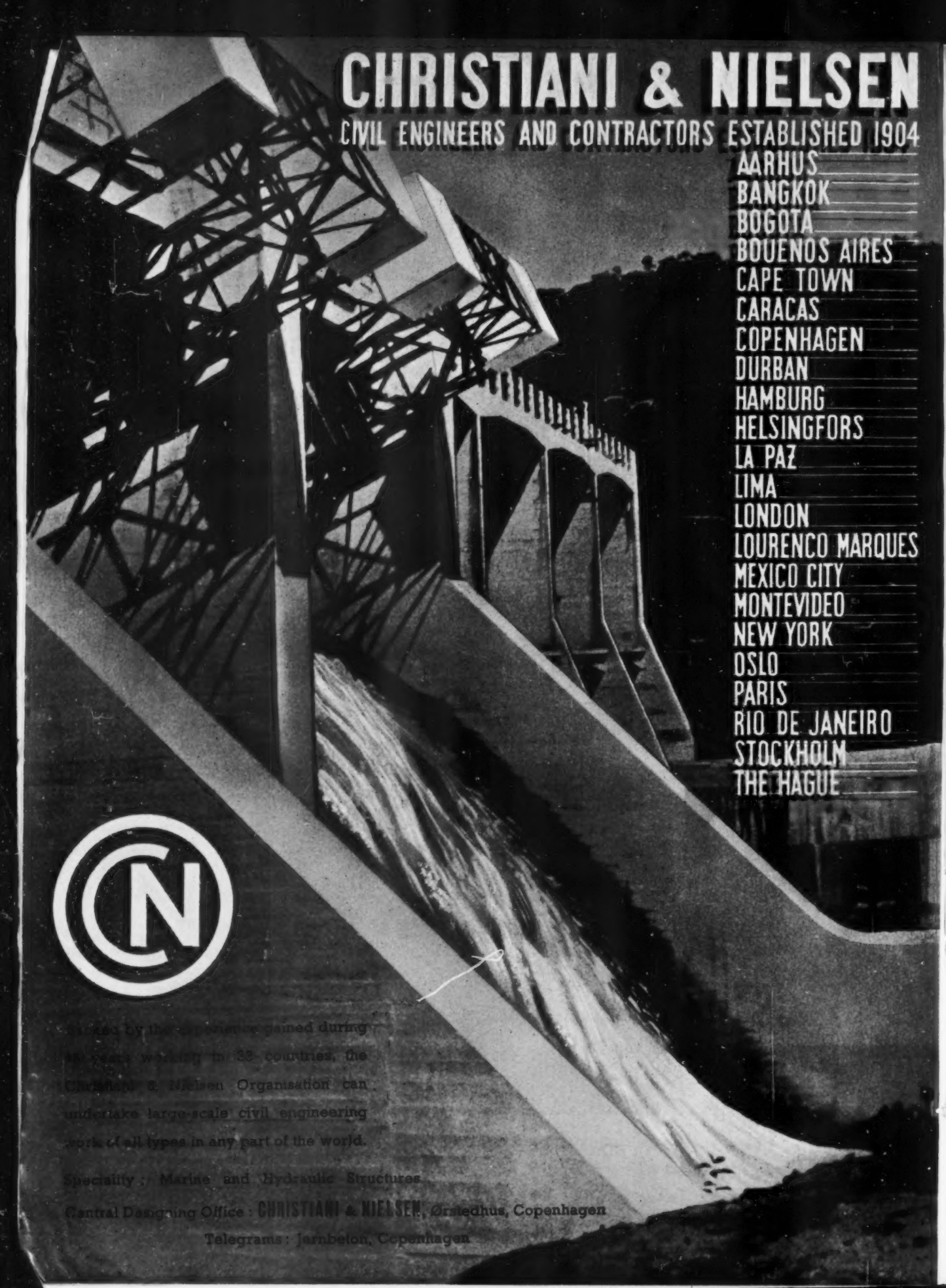
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Specialists in the design, manufacture and installation of Water-Gas and Electrically Welded Steel Pipes for Hydro-Electric Schemes.

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Telephone: Stockton-on-Tees 66117.

WINGET CONCRETE

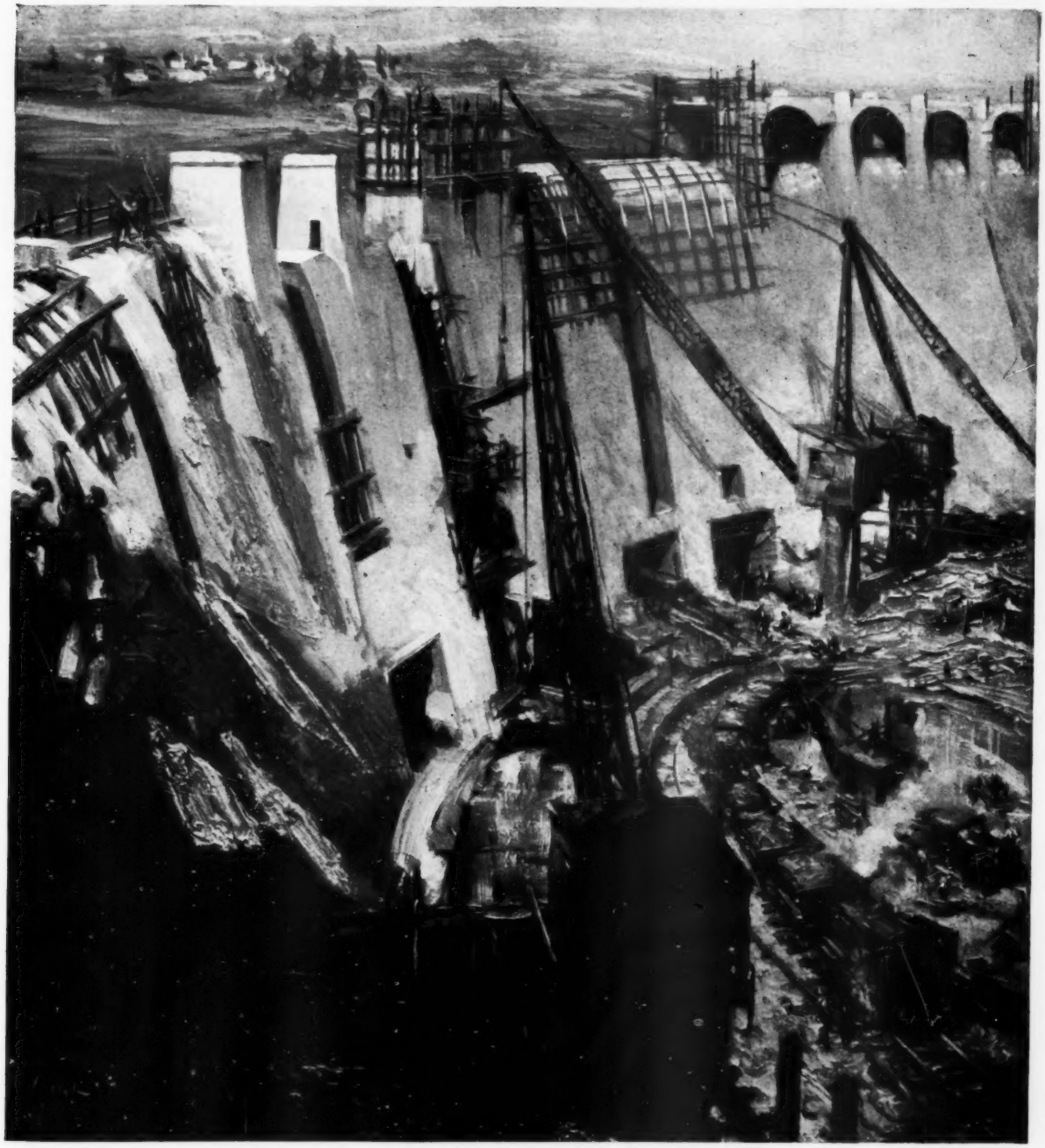
— a tower of strength

The Winget Turntable Batcher Plant operated by J. L. Kier & Co., Ltd., on their contract at the new West Ham Power Station, has a three compartment bin with a total heaped capacity of approximately 50 cu. yds., each bin compartment fitted with a low head room gate. The turntable unit is mounted on roller bearing castors carrying a 24-cwt. dial scale batcher and is capable of charging two 21/14 mixers. Aggregates from stock pile to bins can be handled by dragline, crane or by use of WINGET 30-ft. Boom Scraper and Elevator, the Boom Scraper having an effective radius of 180°.

Reg. Trade WINGET *Mark*

WINGET LIMITED · ROCHESTER · KENT · *Member of the British Export Trade Research Organisation*

Building the Post-war World . . .



Hydro Electric Dams

a job for TAYLOR WOODROW

CONTRACTS RECENTLY COMPLETED AND IN HAND • SEA DEFENCE WORKS • OIL PIPE LINES

UNDERGROUND STORAGE TANKS • POWER STATIONS • DEEP SEWERS (Tunnel and Open Cut)

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Holman ro
for all-round sp
economy in tu

Notice the simple control handle which regulates both direction and rate of feed.

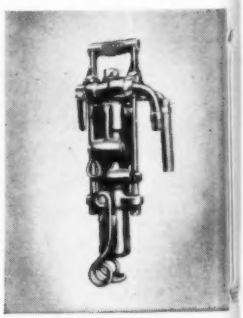
The Holman Roto-Feed Drifter needs no nursing

The Holman Roto-Feed Drifter reduces the manual labour of drilling, requiring less attention from the operator. Its light-weight air motor dispenses with hand-cranking and ensures a constant penetration speed equal to the maximum obtainable with a crank-fed drifter. The speed of retraction is much faster, so that overall drilling time is considerably reduced. This new drifter is exceedingly simple to operate and maintain, and it is built to the rigid standards everywhere associated with the name Holman.

The new Liteloy cradle shown here, when used in conjunction with tungsten carbide tipped Holbits, permits holes of 10–12 feet to be drilled with only two steels. The cradle is made of aluminium alloy, thereby reducing its weight by over 50 per cent.

The weight varies according to type of chuck and cradle used.

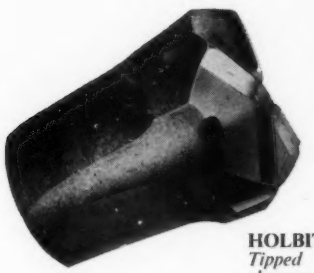
	Bore	Weight	
SL. 200	2½ ins.	114 lbs.	Very light weight for medium work.
SL. 240	3 ins.	168 lbs.	Medium weight for general purpose work.
SL. 250	3⅛ ins.	190 lbs.	Medium to Heavy Duty.
SL. 280	3½ ins.	205 lbs.	Heavy Duty Drifter.



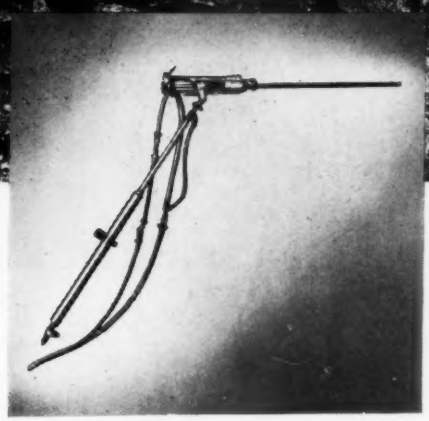
S.L.9D. *A smooth-running, well-balanced drill which has proved particularly effective with the Holman AIRLEG. For soft medium rock. Weight 42 lbs.*

H 31

rock drills
nd speed and
in tunnelling



HOLBIT. *Tungsten Carbide Tipped Bit. Reduces steel changes, increases drilling speed.*

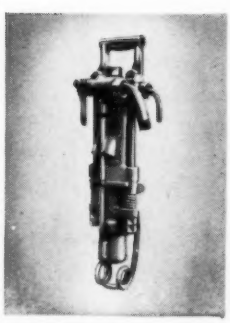


AIRLEG. *Provides uniform feed pressure while supporting the weight of the Handril.*

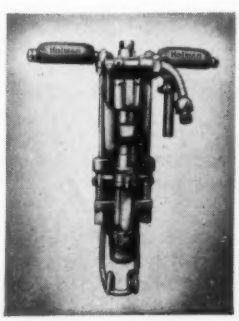
Handril-Airleg-Holbit
the Labour-Saving Holman Combination

The versatile HOLMAN COMBINATION represents the greatest advance in drilling technique for a generation. It saves countless working hours by cutting out the labour of rigging and removing columns and arms as well as transporting drill carriages. In a few minutes it drills a deep parallel hole with a steady forward movement and without needing a steel change. It can then be instantly reset for the next hole. The Holman Combination operates successfully almost anywhere, even on top of a pile of debris.

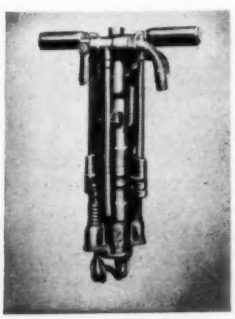
Note—All the Handrils illustrated are especially suitable for use with the Combination.



SILVER DART. *One of the latest Handrils, incorporating patented automatic lubrication. Throttle operated blowing or vented front head. For medium-hard rock. Weight 48½ lbs.*



S.L.200. *A new model especially suitable for use with Holbits. Positive valve action. Rotation is particularly powerful. Weight 50 lbs.*



SILVER BULLET. *Similar to the Dart, but suitable for general purpose work in really hard rock. Weight 58½ lbs.*

Every user of Holman rock drills has the benefit of a comprehensive and expert after-sales service, and consultations on problems of special difficulty can always be arranged.
Further details and specifications of Holman equipment suitable for tunnel engineering will be gladly supplied on request.

The first name
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CAMBORNE . ENGLAND

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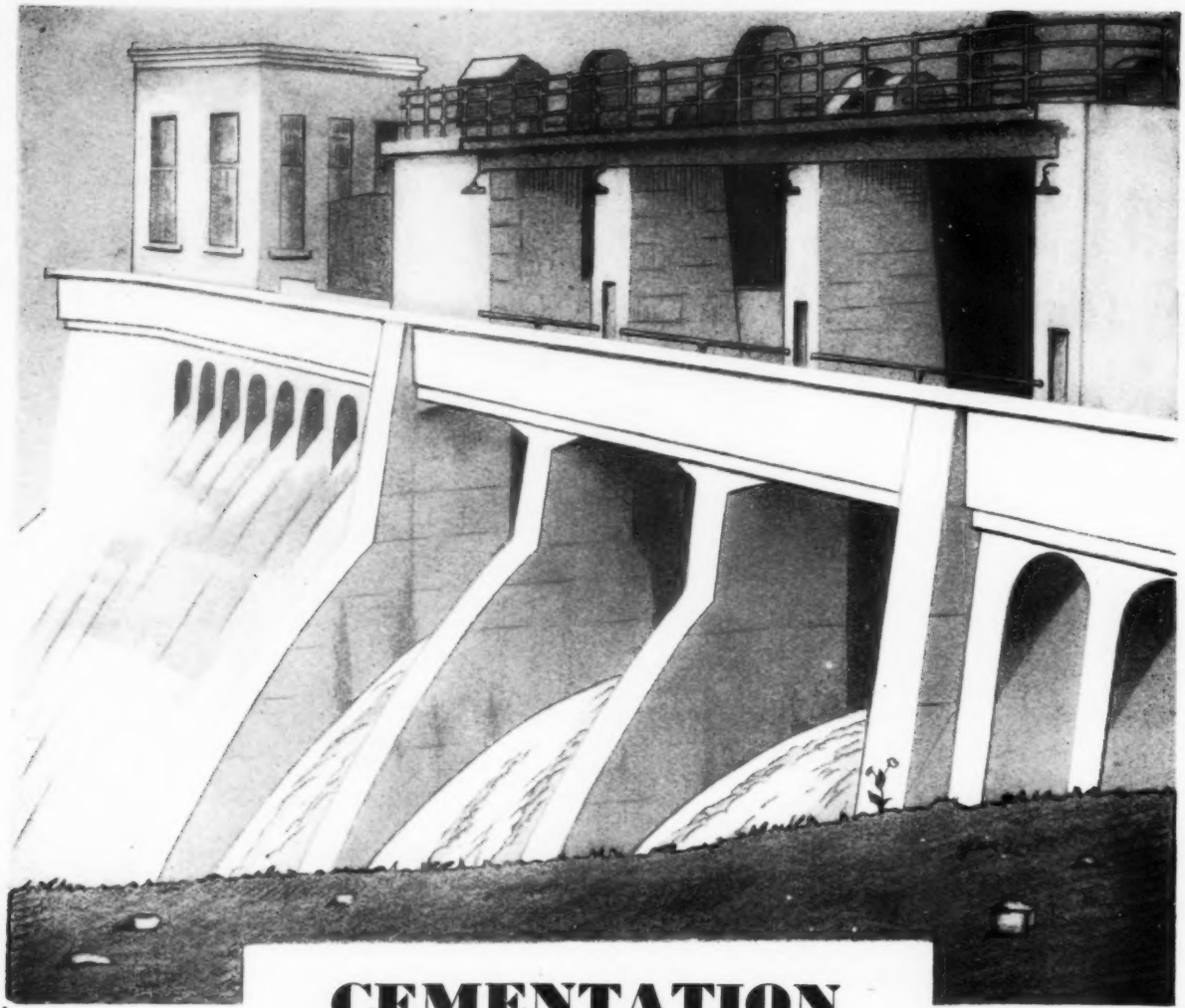

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WATER LOSSES

For nearly half a century we have, by one or more of our processes, successfully prevented leakage of water through, under and around dams, from service and impounding reservoirs, filter beds, draw off tunnels, etc.

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Stabilising and stanching coffer dams and other water retaining structures. Precementation of cut-offs and foundations. Piling. Soil investigation. Geophysical Surveys.

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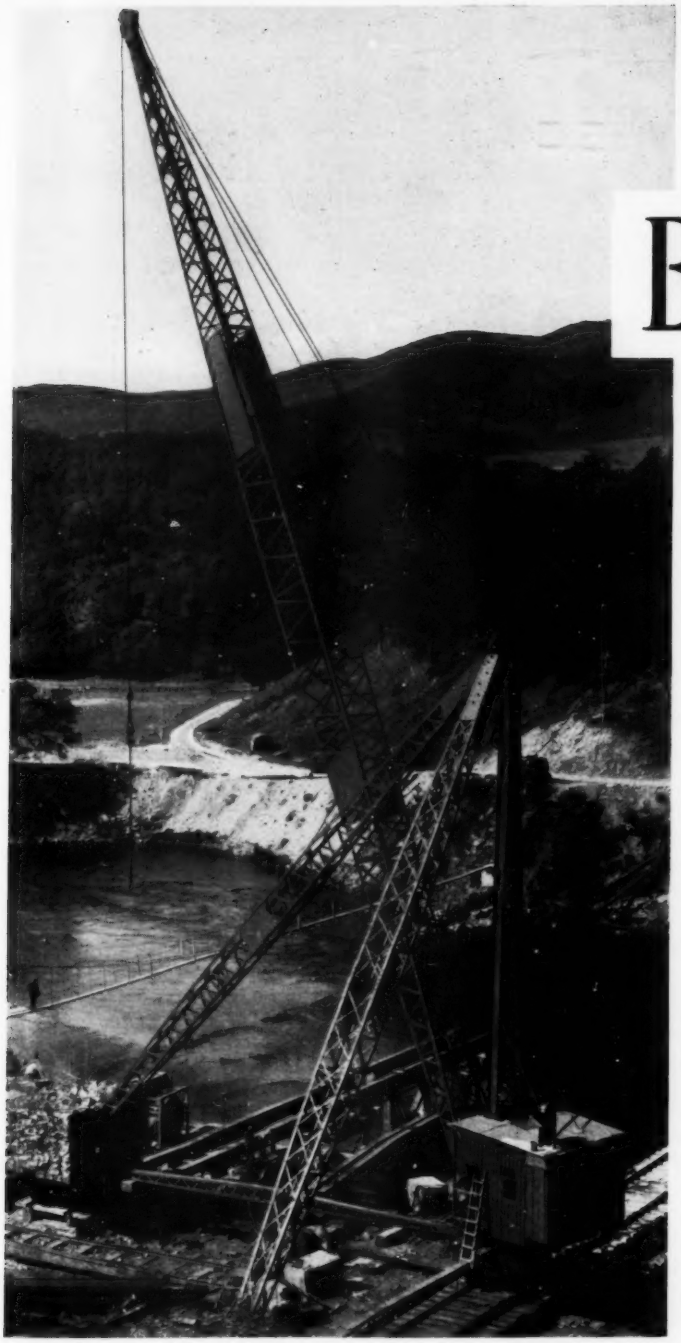
Concrete and masonry works, roads, canals, etc., restored and strengthened in fabric and footings.

THE CEMENTATION CO. LTD. Telephone Don 54177-8-9 BENTLEY WORKS, DONCASTER.



BUTTERS CRANES

for reliability in material handling

These cranes are designed to meet the material handling requirements of engineers engaged on large Civil Engineering contracts and have been developed in a very lengthy experience of this class of work and in a close study of the problems arising.

They are capable of operating under the most arduous conditions with a reliability which virtually precludes breakdowns in the link of handling and feeding points and the ensuing hold up in time schedules.

A large number of Butters Derrick Cranes are at present employed in the North of Scotland Hydro-Electric Scheme where the photograph on the left was taken.

We are always happy to co-operate with engineers in deciding the most suitable types and sizes of cranes for any purpose and shall be pleased to submit designs and quotations on request.

Designers and makers of cranes of all types

Butters Bros. & CO. LTD. ENGINEERS & CRANE BUILDERS

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AERIAL CABLEWAYS

Henderson Aerial Cableways have solved the problem of raising, transporting and depositing concrete, shuttering and other materials for the construction of large Dams and Barrages.

Henderson Cableways are being used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

DERRICK CRANES

Henderson Cranes are chosen so often because of their speed and versatility in lifting materials. Their safety and economy in operation are also assured. Supplied to many leading contractors Henderson Derrick Cranes of all types and capacities can be manufactured for steam, electric, petrol or diesel drive. Cranes can also be fixed or travelling types. Normal sizes are from 10 cwt. to 60 tons Load capacity. With jibs up to 120 feet.

View of Henderson Cableway during the construction of the Claerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund Nuttall Sons & Co., Ltd.

Henderson

Aerial Cableways

AND DERRICK CRANES

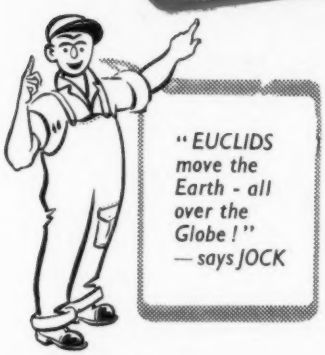
FOR HYDRO ELECTRIC SCHEMES

JOHN M HENDERSON AND COMPANY LIMITED KING'S WORKS ABERDEEN

EUCLIDS set the pace...

...in South Africa

The Illustration shows a Euclid Loader working in conjunction with Euclid Bottom-Dump Wagons during a recent demonstration held for South African Railways and Harbours at Jan Smuts Airfield, Kempton Park, near Johannesburg



Working as a team Euclid Loaders and Wagons can handle almost any material at an average output of 700 tons an hour ***loaded and dumped***—the speediest and most economical method of large-scale earthmoving for all civil engineeering contracts.

COMPLETE AFTER-SALES SERVICE

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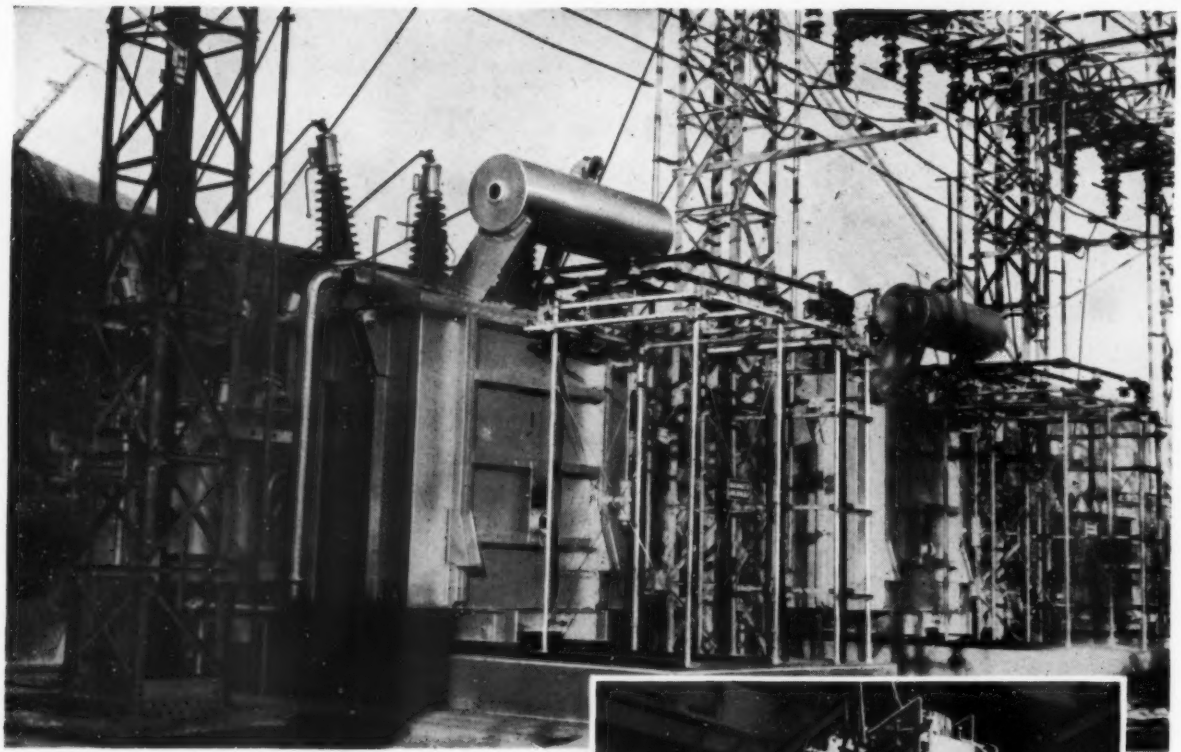
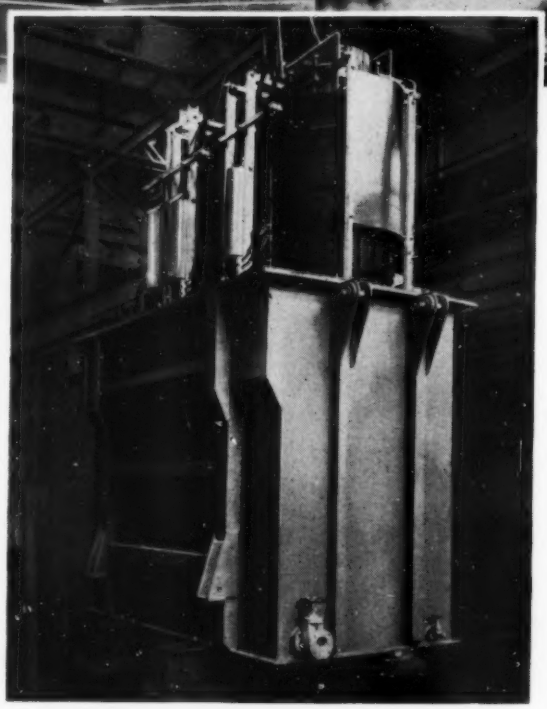
Hydro-electric Equipment





Two of the three 17,500 kVA. 11,000/66,000/110,000 volt step-up transformers, installed at the Mettur Hydro-electric Power Station for the Madras Government.

Core and coils being lowered into tank after final drying-out prior to shipment.

For all plant required for Hydro-electric Power Schemes—Consult BTH

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON CO. LTD., RUGBY, ENGLAND

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MORAR *First completed scheme of the North of Scotland Hydro Electric Board*

Boving

& COMPANY LIMITED

WATER POWER ENGINEERS

RUNNER TYPE
K.43m
Vertical **KAPLAN**
Output 730 h.p.
at 26 ft.
550 h.p.
at 19 ft.
Speed 333 r.p.m.

Whilst the installed units are themselves small, the Scheme is interesting as being the first to be opened: the first underground station in Britain and because it employs the first KAPLAN units to be installed (with one 86 h.p. exception) in the country. The generators were supplied by Bruce Peebles and the first unit came into commission in December 1948.

Manufactured at the Works of Glenfield and Kennedy Ltd., Kilmarnock.

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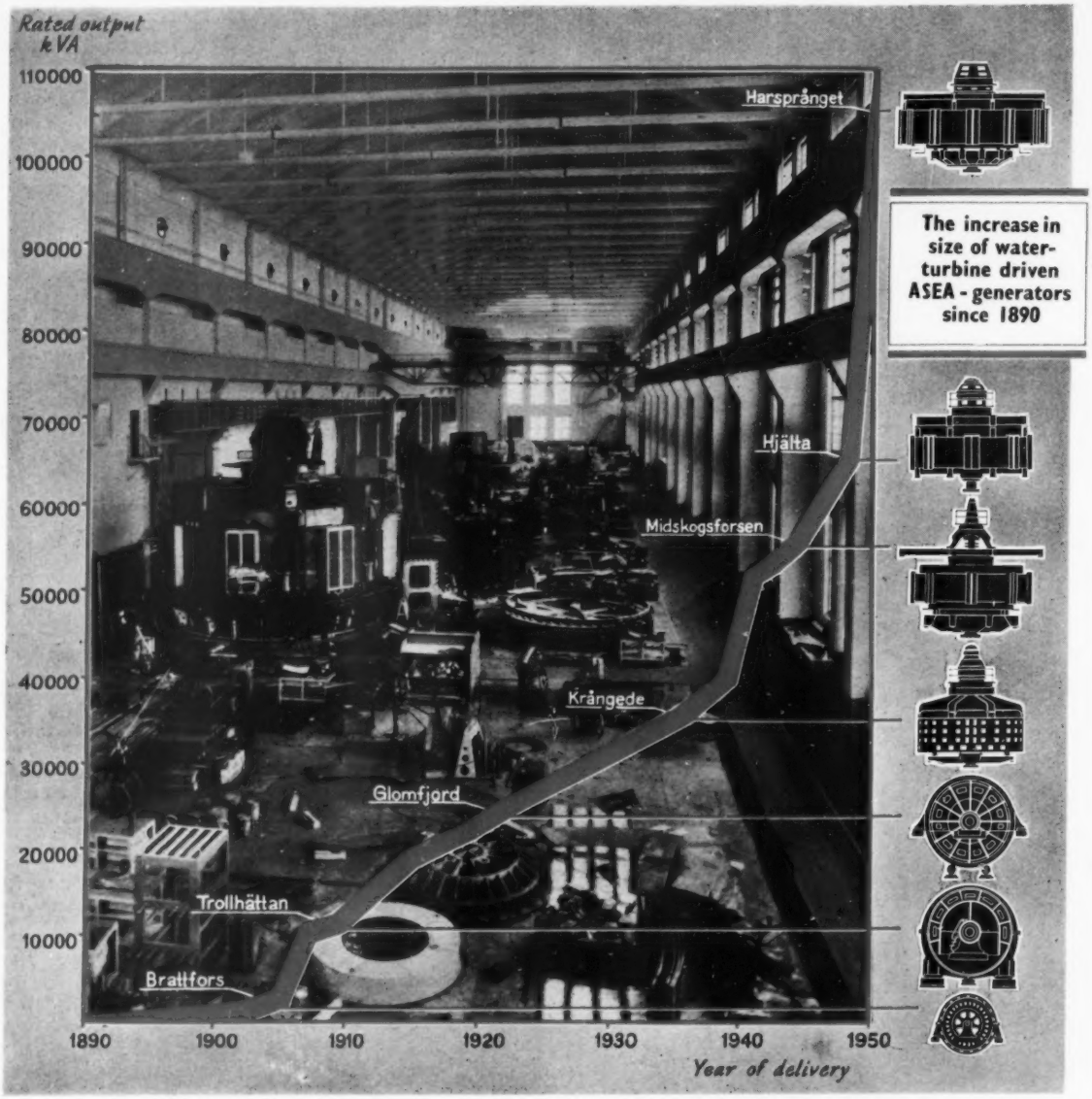
WATER TURBINES & PIPELINES....PULP & PAPER MACHINERY



Development of Electrical Machines

has progressed steadily during the sixty years that have elapsed since ASEA was first granted patent rights for the three-phase system in 1890. Generators have increased rapidly in size, from the 86 kVA machines weighing three tons apiece that were installed in the first power station to the present-day giants rated at 105,000 kVA and weighing 800 tons. During the intermediate years the Company has several times held the world record in generator ratings.

More than 40 generators of 55,000 kVA and above have been, or are in the process of being, built by ASEA, and **six generators with an average output of 100,000 kVA are now under construction.**

The ASEA workshops for heavy machines cover a floor area of 320,000 sq. ft. and are equipped with modern machine tools, transport gear and test plant. The ASEA factories are prepared to manufacture any size of machine that may be required.

A modern ASEA generator is a carefully checked and tested precision product, which on the completion of all the skilled work it involves will fulfil in every detail the guaranteed performance calculated by ASEA.

Consult ASEA for expert advice on all questions concerning projected power plants or extension of existing ones.

Vasteras **ASEA** Sweden

THE WORLD'S MOST POWERFUL HYDRAULIC TURBINES

Newport News Built - For Grand Coulee Dam

Newport News has received contracts for all fifteen of the turbine units awarded thus far for Grand Coulee Dam, the world's greatest power installation. With individual ratings of 150,000 and 165,000 h.p. at 330-foot net head, they are the highest powered hydro-electric units ever built.

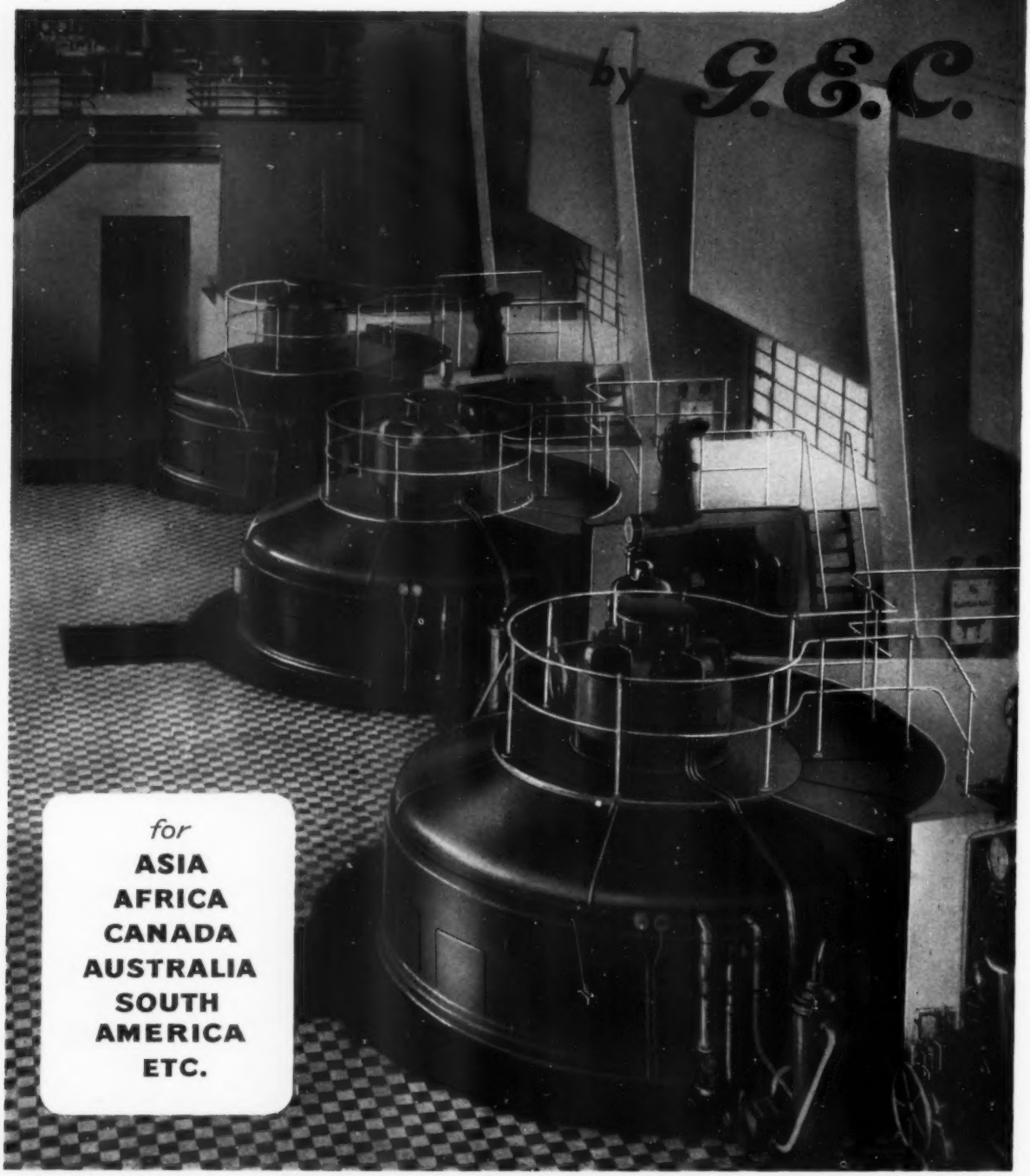
Newport News built its first hydraulic turbine in 1921. Since then contracts received aggregate a rated output of 5,432,000 horsepower. The engineering, efficiency and workmanship of these units have been proven by actual performance in many of the world's great power developments.

Mechanical Rack Rakes
Gates
Large Valves
Pressure Regulators
Penstocks

NEWPORT NEWS
SHIPBUILDING AND DRY DOCK COMPANY
NEWPORT NEWS, VIRGINIA, U.S.A.

HYDRO-ELECTRIC PLANT

by G.E.C.



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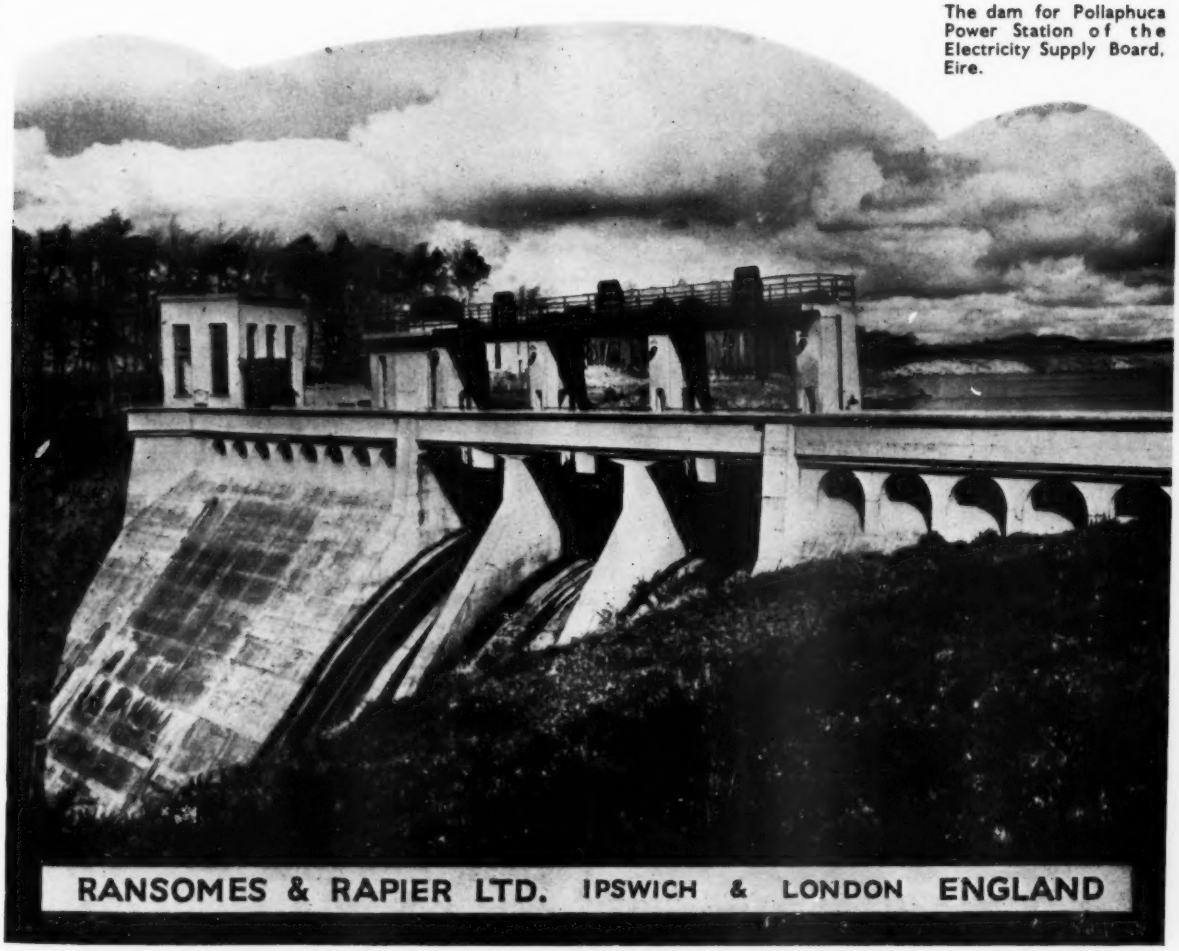
The dam for Pollaphuca Power Station of the Electricity Supply Board, Eire.



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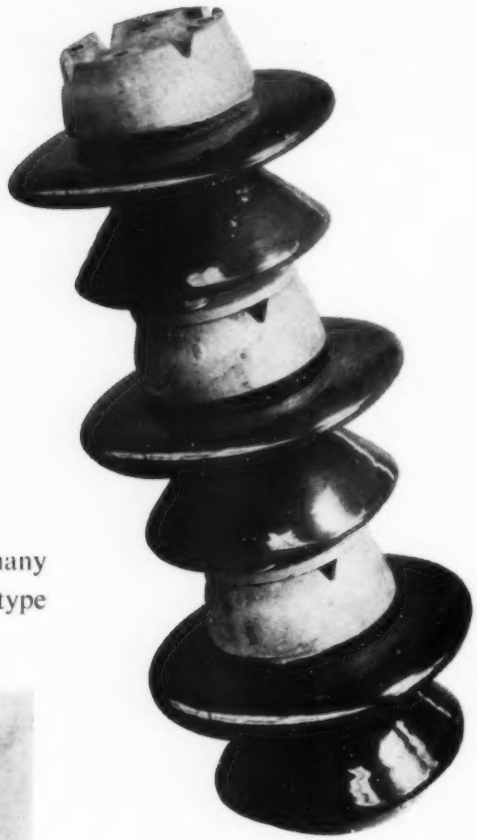
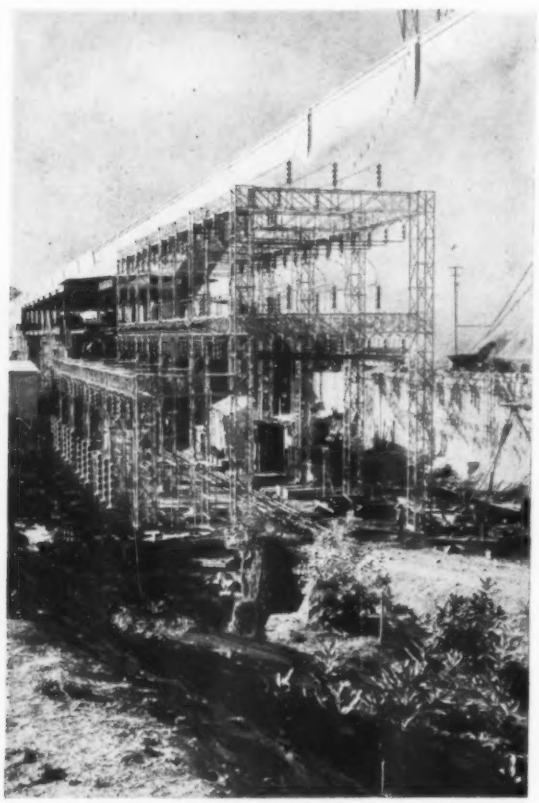


The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



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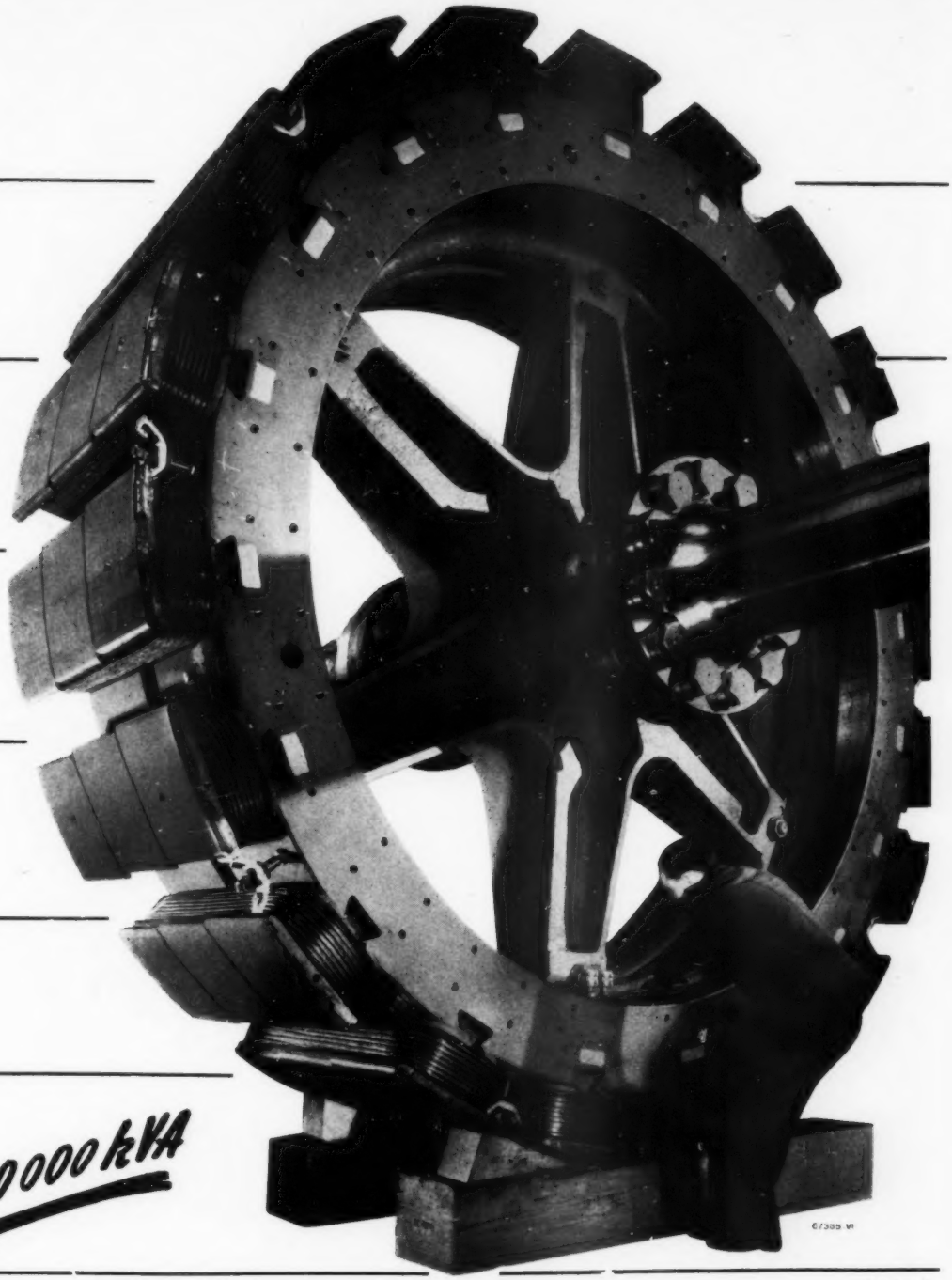

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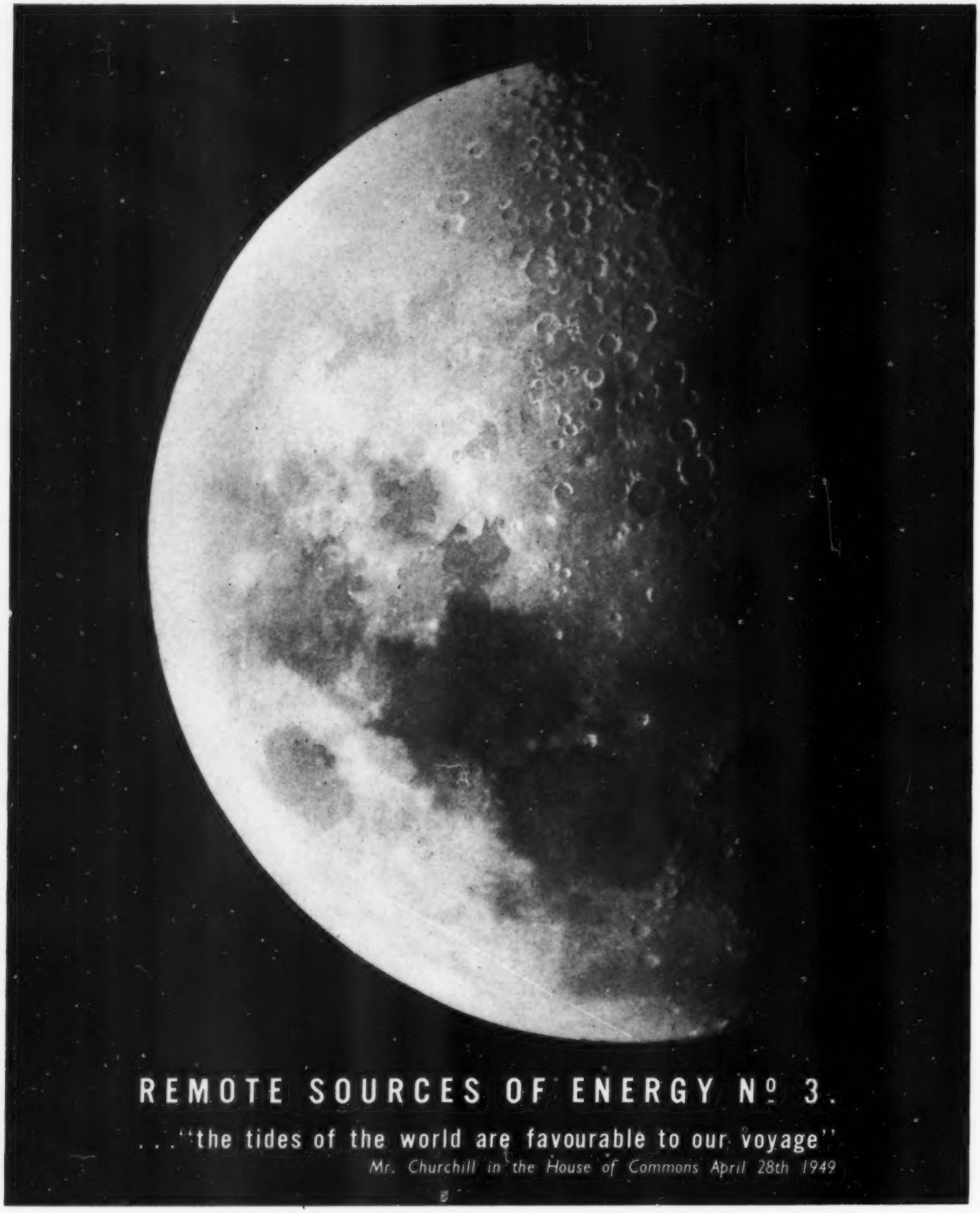
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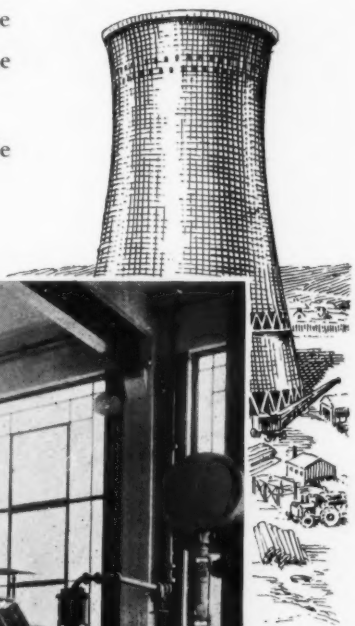
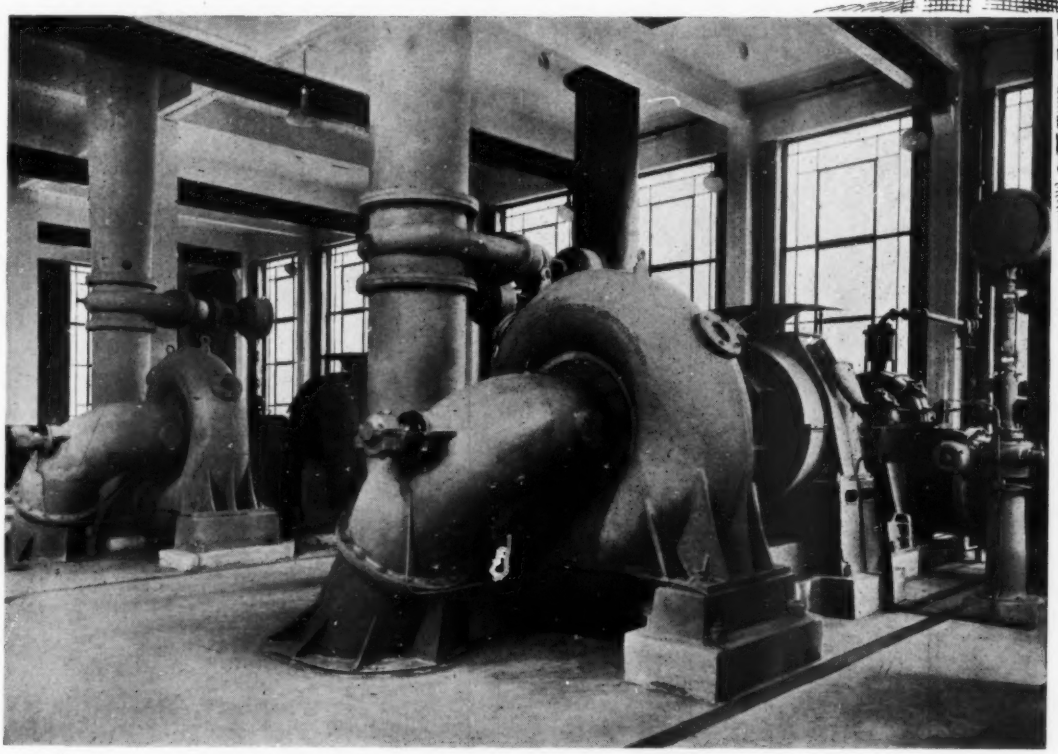
The photograph of the Back o' th' Bank Power Station, Bolton, illustrates a 280 BHP Gilkes Francis Turbine on 45ft. head (in foreground) and a 637 BHP Gilkes Francis Turbine on 102 ft. head (on left).

The Turbines work on returned water from the cooling tower, recovering a proportion of the energy expended in pumping water to the top of the tower. The base of the cooling tower is at a higher elevation than the power station, due to the lie of the land.

Turbines are direct coupled to English Electric motors driving Drysdale pumps which lift cooling water to the top of the tower.





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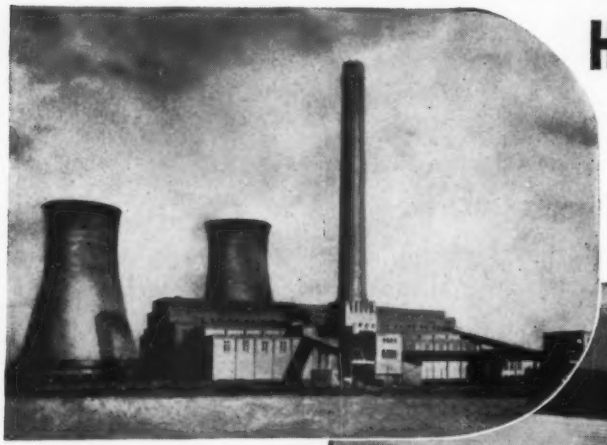
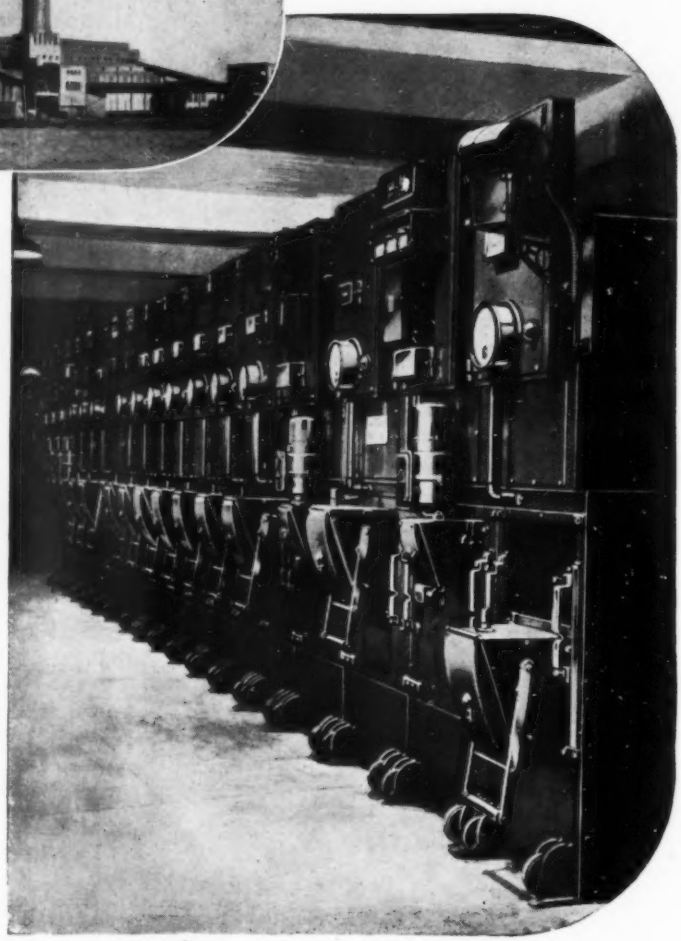
GII

ELLISON HIGH VOLTAGE SWITCHGEAR IN HAMS HALL 'B' POWER STATION BIRMINGHAM





This Ellison 3,300 Volt Air Insulated Switchboard controls the auxiliaries of one of the large generating sets. It is one of several Ellison Switchboards supplied to this new station. The Circuit Breakers on this type of switchboard can be arranged for manual, spring or solenoid closing.

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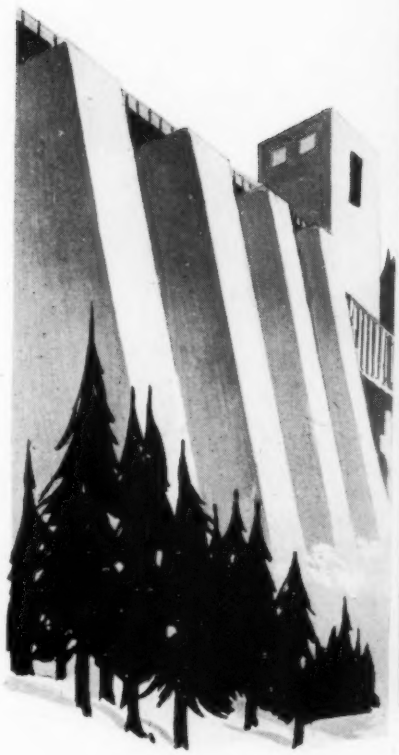

The illustration shows a Rock Drill RH-655W operated in conjunction with a pneumatic pusher and a drill steel with tungsten carbide insert.

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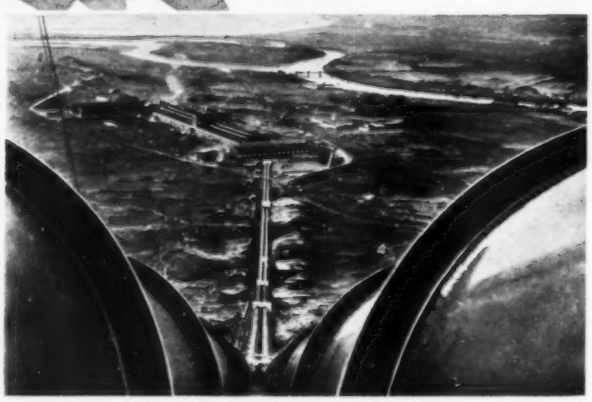
THE two illustrations show views of a section of the Lochaber Power Scheme, which involved the construction of three large Dams, about twenty miles of concrete lined Tunnels, five Pipelines each 3,200 feet long, a Power House, Factory foundations, Tail Race and ancillary works.



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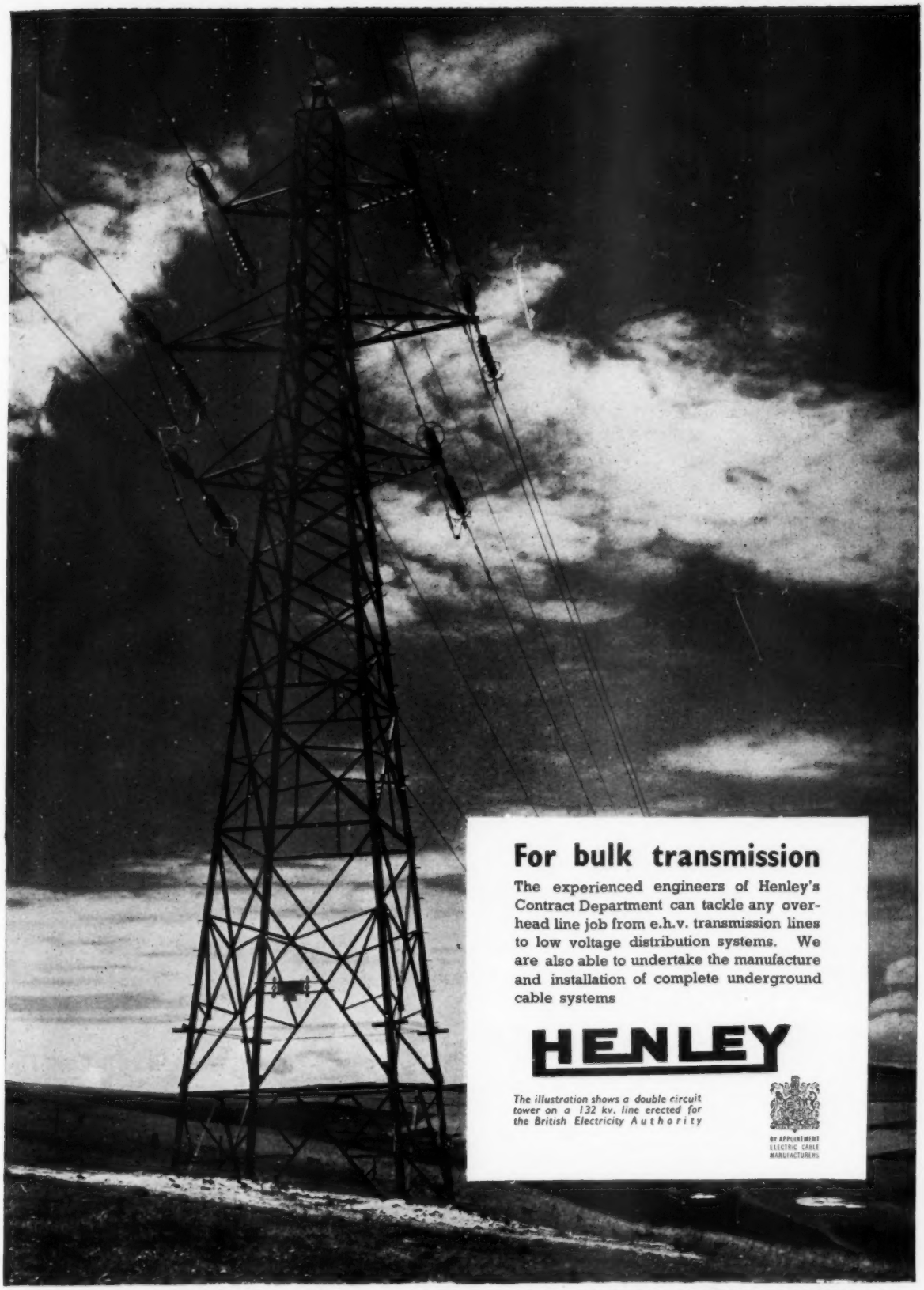
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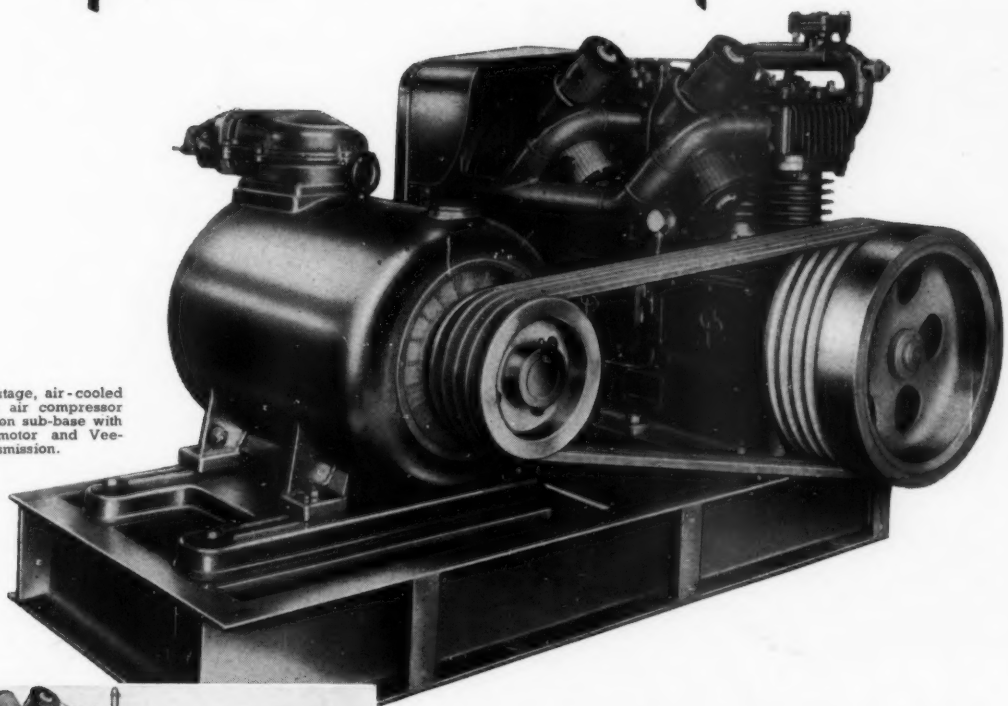
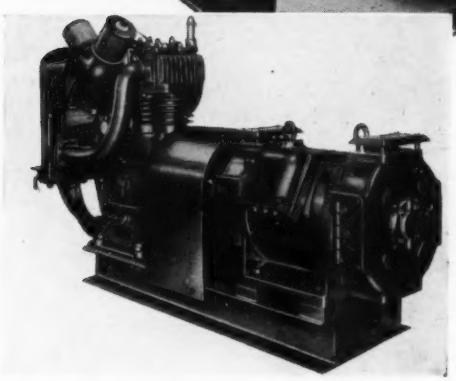


CP two-stage, air-cooled stationary air compressor mounted on sub-base with electric motor and Vee-rope transmission.



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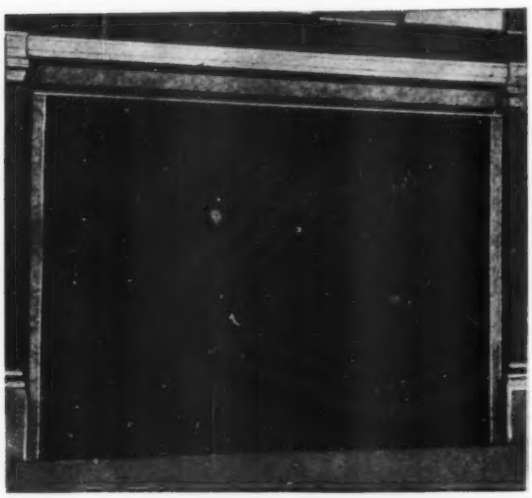

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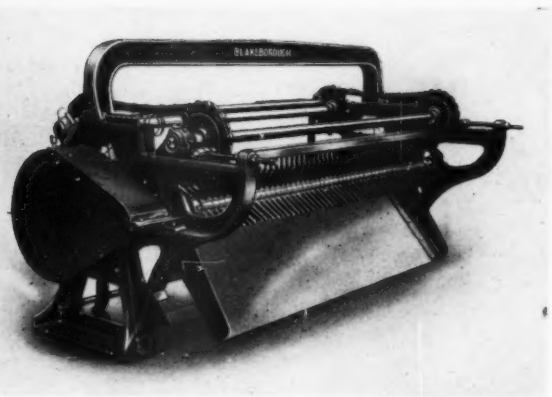

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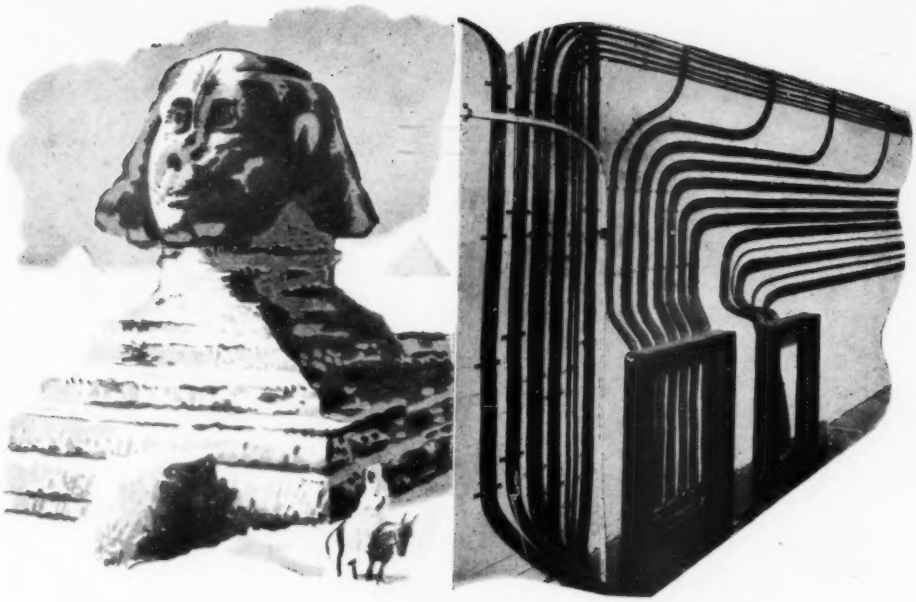

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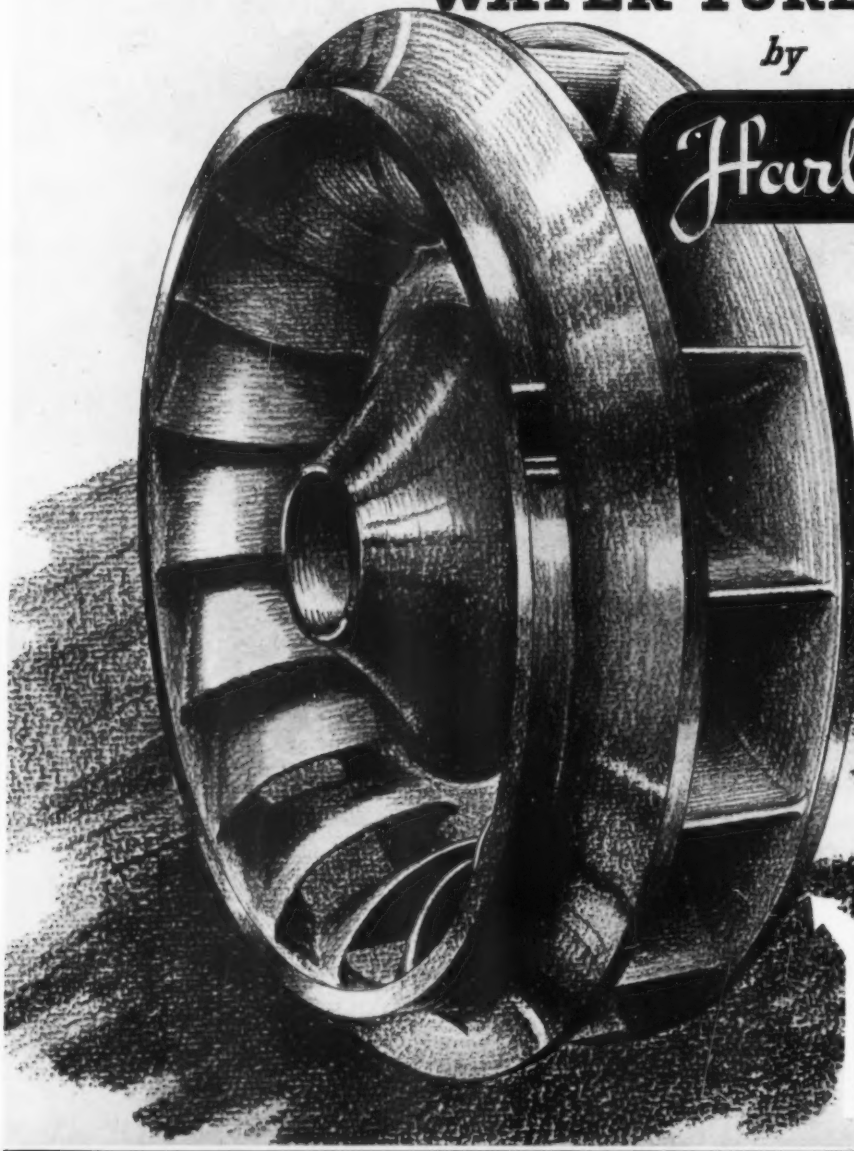

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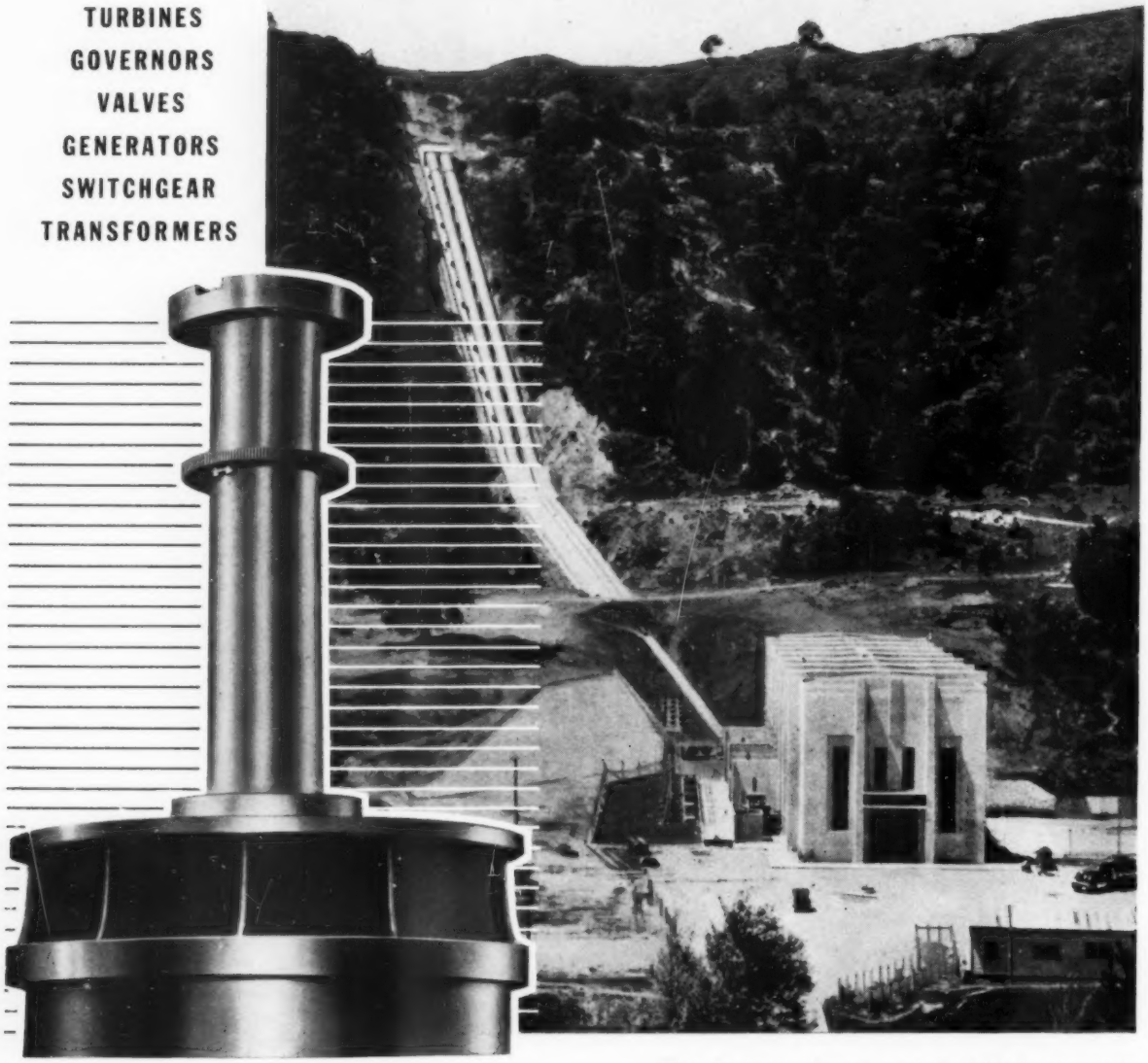

The Piripaua Station of the Waikaremoana Hydro-electric Scheme of the Public Works Department, North Island, New Zealand, contains two 28,000 h.p. vertical reaction water-turbines running at 333 r.p.m. under a head of 360 ft. The operation of this station is completely automatic.

The illustrations show a view of the Piripaua Station and one of the turbine runners.

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A technical journal devoted to the study of all aspects of Hydro-Electric Development

A Field for Exports

PUBLICATION of the findings of the British mission of investigation on the prospects of expanding British engineering exports to Canada forms a most useful and illuminating corollary to the detailed survey of Canada's hydro-electric schemes in a recent issue of *WATER POWER*. It was largely because Canada was importing vastly greater quantities of engineering equipment from countries other than the United Kingdom that the mission was established under the leadership of Mr. E. H. Gilpin, an engineering industrialist of wide Canadian experience.

Hydro-electric and electrical enginering equipment are two principal subjects engaging the attention of the investigators, who underline this journal's statement that only 20 per cent. of the Dominion's recorded water-power resources has so far been harnessed. Moreover they emphasise for future guidance that, of the output of all central power stations, 97.5 per cent. is hydro-electric; the remainder being produced by thermal stations. Extensions to existing hydro-power schemes throughout Canada in the next four years (including the present year) are estimated at about 5 million h.p., or 50 per cent. of present capacity, and assuming £100 for every horse-power produced to cover capital costs of generation, switching, transforming, transmission and distribution plant and equipment the vast total of £500 million will be spent during that period.

" This enormous demand," the report states, " will overtax the capacity of all the electrical manufacturing industry of Canada, the more so since there will also be required a vast amount of equipment for a standardization-of-frequency scheme in Ontario, estimated to cost £50 million." The lengthy and increasing delivery times now being quoted by Canadian manufacturers are causing more inquiries to be sent to the United Kingdom, and although the Mission received numerous complaints regarding the deliveries quoted from the United Kingdom, it was instructive to learn that deliveries in Canada to-day are taking:—Large generators, 2 to 3 years; switchgear 1 to 2 years; large transformers up to 50,000kVA, 1½ to 2½ years; small transformers 200/500 kVA, 12 to 15 months.

" Prices quoted by United Kingdom manufacturers were severely criticised, notably in the Central Provinces. The Canadian purchaser's definition of what he described as ' the right price ' was one that was less than, or at least level with the lowest Canadian or United States price, and some fantastic differences were quoted which could only be accounted for by technical differences in the bids. Generally speaking, however, the criticisms were to some extent justified, and the Mission took every opportunity of explaining that United Kingdom prices for electrical equipment were on a higher level in some cases, principally because of higher costs of non-ferrous and insulation materials, and the Canadian import duties."

The Canadian market, the report warns, presents difficulties for United Kingdom manufacturers, but " the demand will be so great that, provided a concerted and sustained policy is pursued, there are excellent opportunities for British manufacturers to obtain in time a due share of the market, worthy of the high prestige in which the workmanship, design, reliability and performance of British electrical equipment is held in Canada to-day."

The problem of how best to implement the British trade drive in Canada forms an important part of a complementary report on the Mission's tour prepared by Mr. D. Maxwell Buist, M.I.E.E., M.I.Ex., who is well-known on both sides of the Atlantic as Export Director of " Beama " (British Electrical and Allied Manufacturers' Association) and was a member of the Mission. " Of all the methods of trade representation," he writes in a detailed survey of Canada's electrical development and market potentialities, " that of joint or group representation is the one most likely to appeal to the majority of electrical manufacturers, especially specialist manufacturers in the medium and smaller categories of equipment. It reduces expenses in an expensive territory, ensures wider contacts with purchasers, and is more able to afford sub-representation in the principal centres across the whole Dominion. An existing British firm with a branch company, or a branch sales office, may be willing to represent other British makers of non-competitive products. Alternatively a group of manufacturers, with or without agencies at present, and each producing non-competitive and yet complementary electrical products, may get together and

arrange to establish a company in Canada to represent their joint interests.

"This method has already been tried and proved successful in Canada and other territories. It is the method most favoured by Canadian purchasers, who have thereby one firm only to deal with for a variety of products; and, moreover, a firm able to afford and to provide that after-sales service concerning which so many complaints were levied against British manufacturers and their unfortunate representatives. Generally speaking, we fail lamentably in this matter of service compared with that provided by U.S.A. competitors, whose service facilities, including expert personnel, are on tap at the end of a telephone line."

Mr. Maxwell Buist considers that branch factories or branch offices should be established in or near Montreal or Toronto, being within easy reach, by rail or air travel, of the maritime provinces, Ottawa, Quebec City, and the principal centres of industry in Quebec and Ontario. On the subject of publicity the author of the report urges the importance of increasing the circulation in Canada of British technical journals, and the holding of "shop window" exhibitions in the main cities of Canada.

The Snowy River Project

LEGISLATION setting up a commission to develop the £A200 million Snowy River water diversion and hydro-electric power scheme, which is the subject of a special article in this issue, will be presented to the Australian Federal Parliament during the coming session. The Commission, according to Mr. Lemmon, the Minister for Works and Housing, will be known as the Snowy River Electric Authority and would be entirely controlled by the Federal Government, while work on the project would be carried out under the existing Federal defence powers. Preliminary road work, surveys and the building of hostels for workers are already in hand preparatory to the major tasks of tunnelling and dam construction. The Minister believes that eventually the Snowy River scheme will have a power output equal to that of the Tennessee Valley Authority in the United States.

Industrial Expansion Encourages the Scheme

THE main reason, though not the sole one, for pressing forward with the preliminary plans for the Snowy River scheme is beyond question the extraordinarily rapid development of industry in the two principal states of the Commonwealth of Australia. The Federal Prime Minister, Mr. Chifley, stated only a few weeks ago that 2,404 new manufacturing projects had been announced during the three years since the end of the war, and that oversea interests had participated in 226 of them. In some cases an oversea firm had taken the course of establishing a direct subsidy in Australia; in others the expansion had been the result of an oversea firm joining forces with Australian interests, either in founding a new business or extending one that already existed. In this connection it is interesting to note that the engineering industry has attracted more companies from oversea than any other class of work, with aviation, chemicals and oil refining also prominently in the picture.

A Columbia River Authority?

PRESIDENT TRUMAN has raised considerable interest throughout the United States by his recent request to Congress to establish an authority for the Columbia River Development on the lines of the Tennessee Valley Authority. While giving no figures of even approximate cost, the President appealed for unified treatment of the resources of the Columbia Valley, encompassing public power, irrigation, reclamation and flood control, and specifically requested legislation to weld virtually all Federal activities in the valley under one central authority. This consolidation, Mr. Truman urged in his message, would provide a balanced programme for the construction of dams, irrigation works, power transmission lines and other requirements. The Columbia River, nearly 1,350 miles in length, drains roughly 260,000 square miles, or more than twice the area of the British Isles. Rising in British Columbia, on the western slopes of the Rocky Mountains, it flows through narrow lakes into the United States and forms part of the boundary between the states of Washington and Oregon.

Norway's Underground Power Stations

HYDRO-ELECTRIC power plans have an important part to play following Norway's entry into the North Atlantic Pact. Hans Blom, director of the country's newly constituted industrial guard, has already outlined some of the measures to be taken to ensure the maintenance of industrial production and civilian life generally in the event of war. Vital in this connection, he stresses, is the safeguarding of the nation's hydro-electric supplies. At present Norway is building a number of hydro-electric power stations underground, and when these are completed in about four years the country will have an underground generating capacity of 1,200,000 h.p. Fully developed, these plants can produce 2,200,000 h.p., which corresponds to 60 *per cent.* of all the water power at present exploited in Norway. Unlike the power stations, the dams holding the water for the turbines cannot be completely defended against the effects of military attack, but by careful planning a good deal can be done to ensure at least a safety margin. A main aim, it appears, is so to organise industry in general that it becomes virtually an integral part of the nation's defences.

Austrian Engineers Invited to Great Britain

BECAUSE of the lack of knowledge about hydro developments and manufacture in the United Kingdom, while being fully aware (as a result of intensive American propaganda) of developments in the U.S.A., it has been suggested that Austrian engineers

should visit Great Britain to examine our methods of production. Dr. Krauland, Minister of Property Control and Economic Planning, received the proposal enthusiastically, and subject to official contact between the Austrian Ministry and the Board of Trade it is anticipated that a delegation of hydro and allied engineers will visit the United Kingdom sometime in the autumn of this year. It is hoped that a return visit by British engineers will be made to Austria in the spring or summer of 1950.

The Austrian delegation will be invited to inspect actual installations in Scotland and elsewhere, and visits are expected to be paid to manufacturers' works where members will be able to discuss with consultants and producers the technical aspects of the latest hydro developments and problems of transmission, switching and transformation, as advanced by British engineers.

Punjab Power—Sutlej River plans

WESTINGHOUSE Electric International Company has concluded an agreement with the Punjab Government for technical services on a 110,000 kVA power project on the Sutlej River, and for delivery of equipment. The undertaking will cost about nine million dollars, and represents the biggest power development approached since the change of regime in India. Equipment will comprise two waterwheel turbine generator installations, which will be known as Nangal I and Nangal II, and established five or six miles apart. Each station will house two 33-500 h.p. turbines and two 27,500 kVA, 50 cycle generators producing power at 11,000 volts, raised by transformers to 132,000 volts, and three sub-stations will pass the power into the main distribution system. It is estimated that about three years will be required to manufacture and deliver the equipment. The turbines will operate from a head of 98 feet, formed by damming the Sutlej. Apropos this latest project it is of interest to recall the recent assurance of the Prime Minister of India (Mr. Nehru) that " the Government of India have no desire to injure in any way British or other non-Indian interests in India, and would gladly welcome their contribution in a constructive and co-operative role in the development of India's economy."

Experimental Windmill to Generate 100 kW

THE North of Scotland Hydro-Electric Board has placed a contract with John Brown & Company for the design and construction of an experimental windmill in Orkney for the generation of electricity. The windmill will be the first of its kind in Britain. The diameter across the blades will be about 60 feet and it will generate about 100 kilowatts.

This contract has been placed in conjunction with the Electrical Research Association, which at the request of the Government is investigating the practicability of generating electricity on a large scale from the wind. The Hydro-Electric Board is co-operating with the Electrical Research Association and has already made available for wind power research a sum sufficient to meet the cost of the work in the board's area. The construction of the windmill is a further contribution by the board to this research and also a contribution by John Brown & Company, since the cost of the windmill to them will be greater than the contract price.

The Electrical Research Association began preliminary work in Orkney in July, 1948, recording the wind speeds on the exposed north-west coast of the mainland of Orkney. Sufficient information has already been collected to enable the design of the windmill to be put in hand.

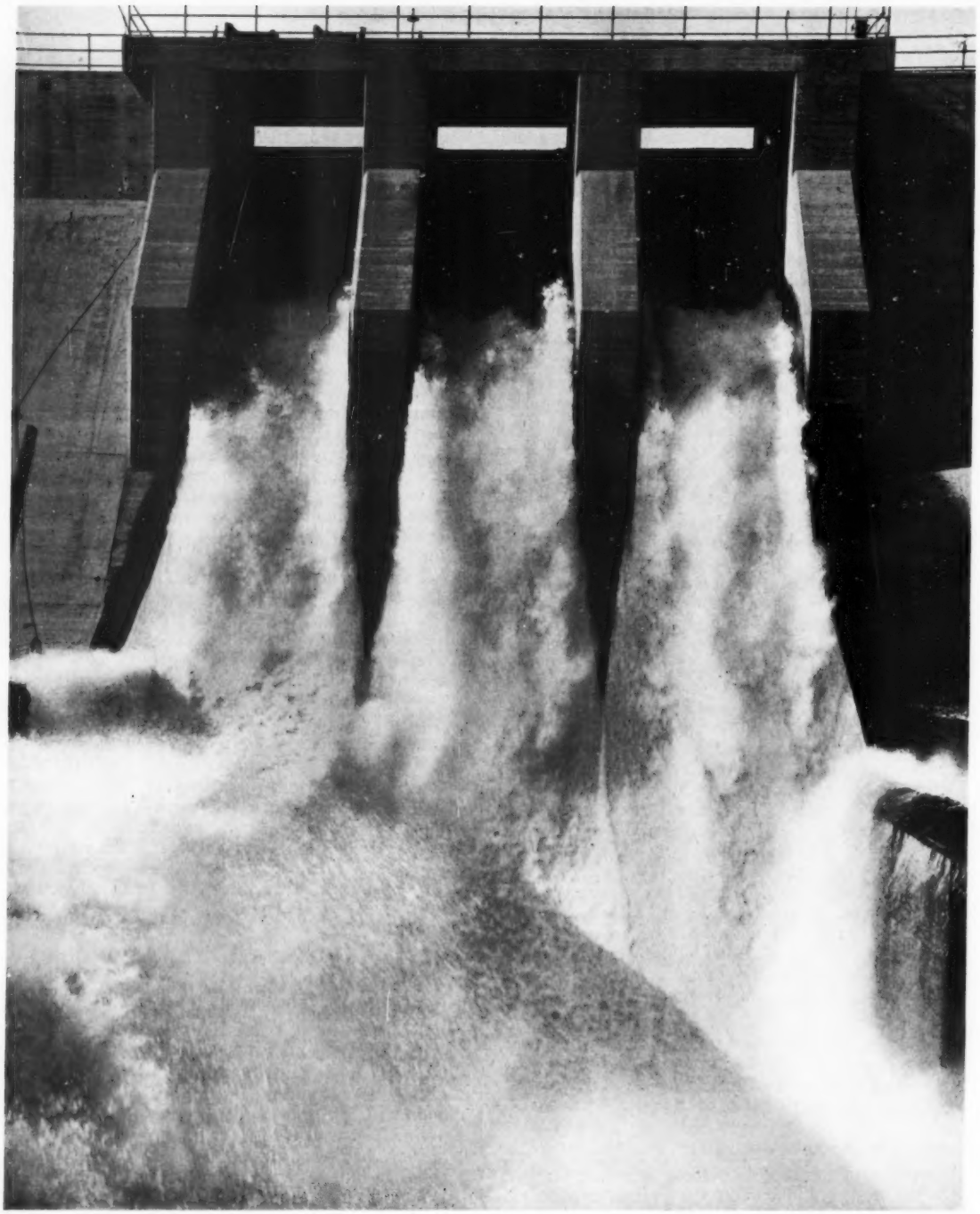
Welsh Schemes and Rural Preservation

TWO decisions have been reached by the sub-committee of the Council for the Preservation of Rural Wales on hydro-electric schemes in north and mid-Wales. Terms of reference to the committee were: " Accepting the need for maximum development of hydro-electric power in Wales, to examine the effect on amenity of the various proposed schemes of the British Electricity Authority; to decide upon action to recommend to the Executive of the C.P.R.W., and to take immediate action in the case of the proposed extensions to the existing schemes at Dolgarrog and Maentwrog." On Dolgarrog the sub-committee " opposes the taking of any water from the Afon Ro, and the taking of any further water from the Afon Dulyn. . . . The amount of water which would be obtained during the greater part of the year would not justify the inevitable loss to amenity and physical necessities which would result if the scheme, as proposed, were carried out." Regarding the Maentwrog scheme the sub-committee, in the absence of more detailed information, while accepting the extensions to the scheme, cannot express a final decision. " It is felt that, if fully informed (of details of the scheme) the sub-committee could be of assistance not only to the British Electricity Authority but to the public in general in the execution of the scheme."

Canadian Hydro-Electric Progress

THE Department of Mines and Resources in Ottawa, reviewing hydro-electric progress in Canada during 1948, emphasises once again the enormous demand for electrical energy in all parts of the Dominion. Practically all this energy is supplied from hydro-electric resources.

The installed capacity in Canada now totals 10,931,018 h.p. an increase during 1948 of 440,095 h.p. It is expected that the next five years will add a further 2,300,000 h.p. to the great resources which this Dominion has created by utilising her rivers and waterfalls. Nevertheless, the picture presented by the department's review is not entirely one of triumphant progress during the year. The low rate of precipitation and run-off in a large area of eastern Canada caused serious power shortages in many parts, particularly in southern Ontario, and in sections of Quebec.



Water boils through the open sluiceways in this striking shot at the new Hydro development at Aguasabon, Canada

The Control of Water

By N. J. COCHRANE, B.Sc., A.M.I.C.E., (Sir William Halcrow and Partners). Consideration is given to the possibilities and limitations of some of the analytical tools that are used for assessing and controlling available water for a hydro-electric scheme

Possibilités et limitations de certains des instruments de l'analyse dans l'évaluation et l'aménagement des eaux pour un projet hydro-électrique. Là ou la statistique détaillée des précipitations permet d'estimer sûrement l'écoulement moyen, l'auteur montre la relation entre la capacité d'accumulation et l'utilisation de l'énergie hydraulique. Il reconnait cependant que les statistiques de pluies et d'écoulement n'ont qu'une valeur très insuffisante, particulièrement en montagne, et l'article se résout à une enquête sur le problème de l'accumulation d'eau à partir d'une information limitée.

Se consideran las posibilidades y limitaciones de algunos dispositivos analíticos empleados para calcular y regular el agua disponible para proyectos hidroeléctricos. En los casos en que las estadísticas anuales de lluvias proporcionan datos promedios de confianza, el autor muestra la relación que existe entre la capacidad de apresamiento y la utilización de fuerza hidráulica. Admite, sin embargo, que las estadísticas de lluvias y de agotamiento de aguas durante largos periodos son extremadamente inadecuadas, especialmente en distritos montañosos, y el artículo hace un estudio de los problemas de apresamiento de agua a base de informaciones limitadas.

IN water power we have the process which was, perhaps, the origin of Tredgold's maxim for civil engineering—"The Art of Directing the Great Sources of Power in Nature for the Use and Convenience of Man." To-day we consider it rather more prosaically as a type of industrial process wherein a variable and often violently fluctuating raw material is controlled, disciplined, and transported as easily as possible to a processing plant where its inherent energy is released in a most flexible and useful form to organised society.

Much has been written about the more obvious parts of the process—the design and construction of dams, conduits, turbines, generators, etc.—for these are susceptible to close mathematical analysis. The other, and perhaps more fundamental, aspects have no such exact treatment, but it is these basic analyses which determine the degree of success of a project and unfortunately there is a limited literature of a useful technical character.

In this article it is proposed to consider the possibilities and limitations of some of the analytical tools available for use in the first stage of our conversion process—the controlling and disciplining of the raw material: *i.e.*, the natural runoff from a catchment area. For purposes of illustration, conditions in Great Britain (particularly the Scottish Highlands) will be used, though the general arguments are not affected.

The first step must be to obtain some idea of the vagaries of the natural material for we are, in the long run, concerned with averages and it is necessary to know how far the material ranges from the average before we can exercise any real measure of control over it.

Annual Rainfall

As rainfall is the source of our raw material, its behaviour is naturally of fundamental importance. Where detailed records extending over a long period of years are available the analysis is not difficult. Generally, however, this is not so and records are extremely inadequate, especially in the mountainous, sparsely populated areas in which we are most interested. Our problem, then, resolves itself into an inquiry as to how close we can get to the true long period average with such records as we have. This was treated in considerable detail by Sir Alexander Binnie in a paper to the Institution of Civil Engineers in 1892, and he reached the following conclusions as regards the relationship of apparent to true average with duration of observations.

AVERAGES OF RAINFALL

Overall period of observation	% deviation of apparent from true long average rainfall
1 year	+51 to −40 %
2 ,,	+35 to −31 %
5 ,,	+15 to −15 %
10 ,,	+ 8.22 to − 8.22%
20 ,,	+ 3.22 to − 3.24%
30 ,,	+ 2.26 to − 2.26%

Little advantage is gained by taking more than, say, 30—35 years of records as inaccuracies of gauging

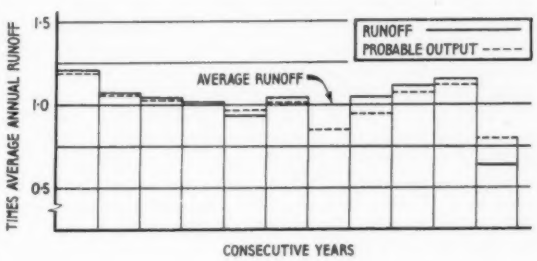


Fig. 1

are of the order of 2%. This fact is used in the preparation of isohyetal (contours of equal rainfall) maps and the so called "long average" in Scotland is based on the period 1881—1915.

Binnie's conclusions were based on a world study of rainfall, and have therefore great breadth of application; but for this country he derived the following additional data:—

1.—Rainfall of wettest year	1.45 × long average rainfall
2.—Average rainfall of the two wettest consecutive years	1.3 × " " "
3.—Average rainfall of the three wettest consecutive years	1.23 × " " "
4.—Rainfall of the driest year	0.66 × " " "
5.—Average rainfall of the two driest consecutive years	0.73 × " " "
6.—Average rainfall of the three driest consecutive years	0.78 × " " "

Annual Runoff

Records of runoff are of much greater direct value to us than those of rainfall, but there are few of them even in a highly developed area like Britain. Fortunately, type results from one river can be applied to other ungauged streams within reasonable limits of distance and similarity of catchment. It is, moreover, reasonable to assume that conclusions and reservations of the same order as Binnie's for rainfall apply to records of runoff in this type of country, though the runoff of the driest year probably falls to about 60% of the long average.

The usual process for estimating the long average runoff where river gaugings are not available, that is in the great majority of cases, is to take the long average rainfall as given by an isohyetal map where available and to subtract long average losses due to absorption, evaporation, etc. Considerable mathematical ingenuity was at one time shown in the calculation of these losses, but one suspects that if enough is known about the catchment in question to apply the formulæ correctly, one would also have a good idea of the losses. For the Scottish Highlands a long average loss of from 12 in. to 15 in. depending on the type of catchment is reasonable and has been checked in some cases by river gauging.

It can be seen from Fig. 1 that the annual variations in the natural runoff are large enough to create economic difficulties in smoothing them out, but they are not so great as to make the problem unmanageable. Under these conditions, allied to our inability to forecast climatic conditions more than a few days ahead, a high utilization hydro-electric scheme would need to have a very large reservoir capacity indeed if its output was to remain constant throughout the years. Generally the output will fluctuate, but much less so than the runoff. Except for isolated schemes serving fixed loads this is not a great drawback.

The Flow Hydrograph

When we come to consider runoff in more detail: *i.e.*, in shorter time increments, the range of departure from the average naturally becomes very much greater, and it is at this stage that understanding of types of behaviour becomes so very important; otherwise, the mathematical treatment may become laborious and aesthetically unsatisfactory.

If we plot the daily runoff from a catchment area

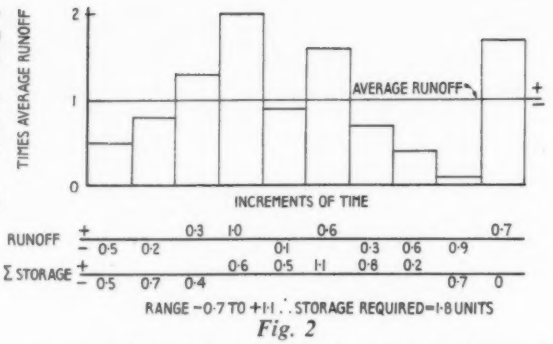


Fig. 2

over a period of time we obtain a flow hydrograph as shown in Fig. 2.

By drawing a line representing the average flow over the period, and by integrating the amount by which the natural runoff exceeds or is less than the average along the curve, we can say what volume of storage would be required if we had wished to draw off the average flow at a constant rate throughout the period. If we had wished to draw off the total amount in any other way the method is exactly the same though the result might be very different. This process is, of course, classical and part of the basic education most engineers receive but it has at least two major practical limitations.

a.—It is primitive and requires the expenditure of much effort. As hydro-electric schemes are generally the result of a number of trial arrangements the use of the tool becomes over arduous.

b.—The necessary statistical information is only rarely available for, as already pointed out, relatively few rivers have been gauged at all and those may not have been gauged over a sufficiently long period.

In practice, therefore, the straightforward flow hydrograph tends to be of academic interest only for initial investigations though it has some value as a check. It can be rearranged, however, in a different form with other uses.

The Flow Duration Curve

If we take the unit flows for the period in question and arrange them in order of magnitude we can plot a curve as in Fig. 3.

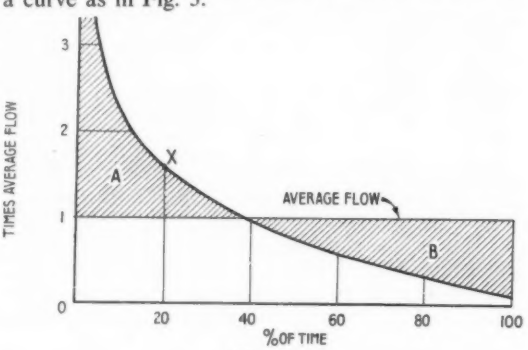


Fig. 3

Generally it is plotted as a curve of flow against *percentage* of time, being thus called a "flow duration" curve, and we can say of any point such as X, representing a flow equal, in this case, to 1.6

times the average flow, that this flow or greater will obtain for 20% of the time.

As before, if we draw a line representing the average flow over the period the apparent storage necessary to regulate this is obtained by integrating along the curve. In this case, by virtue of the shape of the curve, it is given by either area A or B which represents the most severe storage condition possible for the period under consideration. By itself, over a short period, this storage is of minor interest but the curve tends to be plotted as a long period flow duration curve and the resulting storage assumed to be the true storage required over a long period. In temperate climatic conditions this gives a fairly reasonable value for storage requirements; but it is no more than the fortuitous result of a mathematical trick whereby the flows are arranged in the worst possible order, and is certainly not a true analysis of the problem. Further than this the time ordinate can only be taken as equivalent to a maximum of one climatic cycle: *i.e.*, one year, otherwise the resulting storage required becomes ridiculous.

The use of a flow duration curve for evaluating storages should therefore be carried out circumspectly. The curve has a measure of usefulness, however, in the handling of problems involving several reservoirs and power stations in series or acting as a coherent whole; but this is a large subject in itself and outside the scope of this article.

The shape and construction of the curve, however, have a much more valuable interpretation. Consider a catchment with no storage possibilities and having a flow duration curve as in Fig. 4, from which we

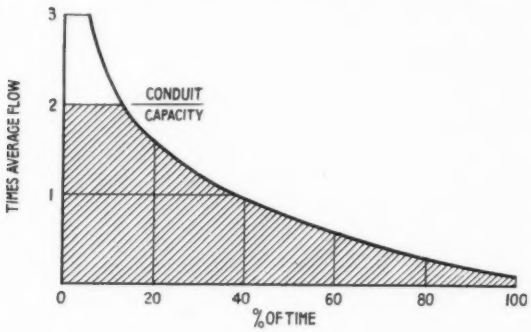


Fig. 4

wish to abstract as much of the runoff as is economically possible.

Obviously a conduit of great capacity would be required if we attempted to abstract all the water. If, however, we instal a conduit capable of handling say twice the average flow from the catchment we could divert all the water represented by the hatched area. This might well be of the order of 85% of the total, which is a point of considerable economic importance. In practice it means:

a.—That conduits diverting unregulated catchments can be of reasonable size while producing a high *percentage* of the available water.

b.—That the so-called " run-of-river " schemes —*i.e.*, those with no storage facilities—do not require uneconomically large plant installations and conduits to achieve a high utilization of the water available. This type of scheme, which by itself has only a limited value to organised

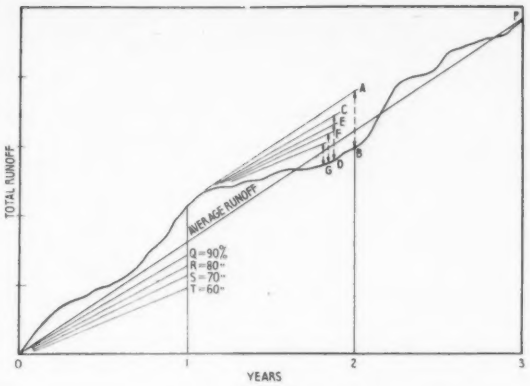


Fig. 5

society, becomes of great value in a grid system consisting of mixed steam and hydro-electric stations where the other stations can be used to regulate the overall output.

The Mass Curve

If, instead of plotting actual intensities of discharge, we plot the summation of discharge, we obtain the classical mass curve. As before, the main drawback to its practical application is lack of statistical data. Assuming, however, that we had enough records to plot the summation of the discharge over a period of years (as in Fig. 5) and wished to know how much storage would be required to equalise the runoff over that period we simply draw a line parallel to O.P., representing the average rate of runoff, so as to obtain the maximum ordinate A.B. This gives the maximum storage required in units of volume. Any other arrangement of drawoff would give its equivalent ordinate.

Now this process in itself is rather too primitive to use in widespread hydro-electric development where a considerable number of streams and arrangements may have to be investigated and storage may not be easy to obtain. Generally the problem resolves itself into starting with a possible storage and working back to a possible rate of drawoff. For this purpose a most useful type of curve can be derived directly from the simple mass curve.

The Utilization Curve

If, on Fig. 5, we draw lines OQ, OR, OS, etc., representing different rates of drawoff and derive the appropriate storage ordinates CD, ED, FG, etc., we can plot a curve of permissible rate of drawoff, generally stated in terms of *percentage* of long average, against storage, generally stated in terms of days of long average runoff. This is called a utilization curve and is one of our most useful approaches in the rational handling of the storage problem.

If we draw the curve to take into account a long period of years including a very dry period we can say that the curve represents the amount of water, and incidentally the power output, which can be guaranteed year in, year out, by the storage available —*i.e.*, the " firm output " of the scheme. Although this gives the guaranteed minimum output it is not a realistic way to gauge the long average output of a scheme. If we were to modify the output in the very dry spells, which in this country are statistically a

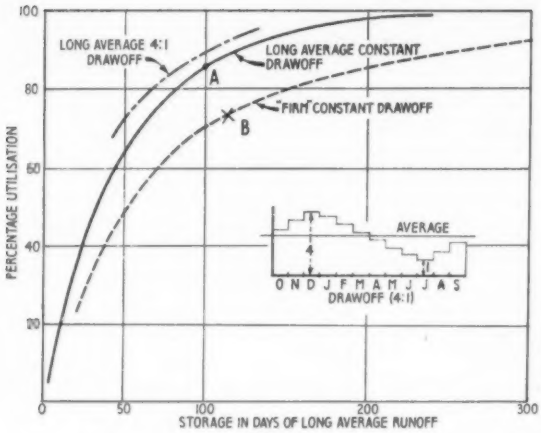


Fig. 6

small *percentage* only of the more normal years, we can draw another curve for long average output as in Fig. 6.

As pointed out earlier, very few high utilization schemes can hope to smooth out their output completely over a period of years and this curve gives a fairly close figure for the true long average output. This " long average " output in electrical units is generally rated as X " firm " units + Y " spill " units —the firm units producing revenue at a higher rate per unit than the spill units.

If, instead of assuming a constant rate of drawoff, we take it to vary seasonally as load demands generally do—*i.e.*, low in summer and high in winter —we might at first sight expect a considerable increase in the *percentage* utilization, since the natural runoff also varies somewhat in this manner. However, only a relatively limited improvement obtains on the basic curve as shown in Fig. 6. The reason is that in winter the months of high runoff may be, and often are, out of phase with the months of high demand. Indeed the freezing-up of a catchment may cause the almost complete cessation of runoff. Normally the storage available is in fact only a relatively small part, say 30% or less, of a year's runoff and even one month of winter runoff out of phase with the demand puts a considerable strain on the reservoir.

Reverting to Fig. 6, it will be noted how this type of curve simplifies and eases the mathematical effort if a large number of schemes have to be investigated. Once the storage available and the type of demand curve are known it is easy to arrive at a figure for the output available. Apart from this the curve itself leads to some important general deductions:

1.—Beyond a point such as A, in this case 100 days' storage and 87% utilization, the value of storage falls off rapidly, and it is problematical whether it is worth while trying to increase the utilization by storage alone beyond this point. As firm units are worth more financially than spill units there is a natural tendency to try to increase the firm output of a scheme by increasing the storage. Beyond a point such as B the economics of this course may be somewhat questionable as the cost of the water retaining structures will normally be increasing rapidly for a very small gain in firm units. When a requirement for additional firm units arises it would probably be better to investigate an additional scheme on another catchment. For the same additional capital outlay one might obtain at least as many additional firm units with a considerable number of spill units as well.

2.—When the lower end of the curve is considered it can be seen that utilization is very sensitive to even a few days' storage either way. As the curve is so steep, and as it is difficult, moreover, to obtain accurate points to plot, values of the *percentage* utilization should be abstracted with a measure of caution in this zone.

Very high utilization factors are sometimes envisaged in hydro-electric schemes; but it is doubtful if these can really obtain in practice except in schemes with fairly large plant and conduit installations—say equivalent to three times the average—and relatively unlimited absorption of output. Hydro-electric schemes working into a grid, in conjunction with steam stations, tend to enter this category as the steam stations can reduce output during periods of high output from the hydro-electric stations. Where schemes are isolated, and have to work to a relatively fixed load demand, the utilization of water will be of the order given by the long average curve.

As an example of how the utilization can be affected by the delimitations of output one can quote a large scheme designed to serve a general mixed load which has storage facilities to give a utilization of about 88% with load curve working. The plant can absorb about 2½ times the average runoff and if allowed to do this when the water is available the utilization is estimated to rise to about 96% with the judicious use of storage in the wet season.

Operational methods can therefore affect improvements in the utilization in the high *percentage* zone and are undoubtedly of much more value for this purpose than storage. The improvement is, however, dependent on the operator's climatic prescience and is thus not susceptible to exact analysis.

The basic analytical tools useful in the solution of storage problems have now been set out. As in all branches of engineering the degree of perfection of the finished product is a function of:

a.—The way in which the basic tool is modified to suit the special job.

b.—The intelligence with which the tool is used.

Mistakes in reservoir design—and over-design is also a technical mistake—are generally either very costly or irremedial, and a thorough grasp of fundamentals and types of behaviour is of the utmost importance in so inexact a science.

NEW INDUSTRIAL BUILDINGS

Industrialists who wish to erect new buildings or extend their present premises can obtain useful advice from " Industrial Building," the official booklet issued by the Economic Unit of the Treasury. The way in which Government departments can help in getting permission to construct is clearly shown both before and after the Ministry of Works has examined the technical plans for the buildings. Valuable appendices give full information on the types of building and civil engineering sponsored by the various departments, and a complete list of titles and addresses of the regional controllers for the sponsoring departments. The booklet can be obtained free of charge from any regional office of the Ministry of Works, the Ministry of Supply or the Board of Trade.

Snowy River

By Our Special Correspondent. Official consideration is now being given to a report on this great Australian project which might eventually have a power output equal to that of the T.V.A. in America. The principal recommendations in the report are discussed here.

Le gouvernement Australien étudie un rapport sur le grand projet hydro-électrique de la Snowy River, dont le débit pourrait finalement atteindre celui de la "Tennessee Valley Authority" aux Etats-Unis. L'auteur, discutant çi-dessous les principales recommandations de ce rapport, souligne que l'aménagement des eaux de la Snowy contribuerait à l'irrigation d'un vaste territoire en même temps qu'il offrirait au développement industriel une production considérable d'électricité. Il mentionne aussi l'important projet de Kiewa et ses prolongements.

Ahora se está considerando de manera oficial el gran proyecto de Snowy River en Australia, el cual eventualmente proporcionará una producción igual a la de la Autoridad del Valle de Tennessee en los Estados Unidos. El autor discute las principales recomendaciones del informe y muestra que la utilización del agua del Río Snowy permitiría el riego de grandes extensiones de terreno, al mismo tiempo que proporcionaría grandes cantidades de energía eléctrica para fines de expansión industrial. También hace referencia al importante proyecto de Kiewa y sus extensiones.

WHETHER the potential water power resources of a country should be devoted primarily to the generation of electricity or for irrigation purposes, where both services are needed, is a problem not easily solved. It is one which confronts Australia to-day.

Some 13 years ago a Commonwealth conference decided that whenever a conflict arose between irrigation and power interests in harnessing the waters of a river, the considerations of irrigation must be placed first. Such, in short, was the eternal lesson of the drought; and the decision was a natural one for Australia—in those days. But with the promise of extensive industrialization in the south-eastern States, where Australia's outstanding example of wasted water power—that of the Snowy River—is situated, it may well be that in years to come, when present plans mature, they will be quoted to the world as a splendid example of compromise on two great issues. Both are of vital importance to the economic life and progress of the country and its people—power for industry and adequate irrigation facilities.

The Snowy River Scheme, although to-day only in its embryonic stage, is by far the largest power project ever visualized for Australia. Its capital cost, the Federal Prime Minister, Mr. Chifley, has told us, will be between £A166 million and £A185 million; and the Federal Government experts, with representatives of New South Wales and Victoria, are now giving their final consideration to a report on the scheme that will determine its main outlines.

Broadly speaking the plan makes provision for the waters of the turbulent and untamed Snowy River, and others of the Australia Alps, to be utilized both for hydro-electric generation and the supply of big new irrigation areas. The estimated power output of the entire project is between 1,720,000 and 1,750,000 kW, but expert opinion has advised the division of this scheme into two parts. The first part, recommended by both Federal and State officers, consists of operations which would divert roughly two-thirds of the water of the Snowy River into the Murrumbidgee, the principal river of New South Wales, for use in the cities and countryside of that State. This recommendation is now before the Victoria and New South Wales Governments, and carries with it the unanimous support of both Federal and State officers. So far as details are available the effect of this "first step" proposal would be to increase the flow of the Murrumbidgee by about 569,000 acre feet of water a year; though when the necessary dams are in operation the volume of water brought under control would be doubled. The principal recommendations for the entire project are:

1.—Immediate adoption of a scheme which would divert two-thirds of the flow of the Snowy River at Jindabyne into the Murrumbidgee, via the Tumut River.

2.—Immediate surveys for the construction of this scheme.

3.—Further investigations to decide whether the complete scheme should divert the remaining third of the Snowy River water into the Murray (Victoria's main river) or the Murrumbidgee.

At the time these recommendations were put forward it was also laid down that the work of investigation should be completed within six months "to enable the bigger scheme to be planned." It is probable, therefore, that by now the experts are at least approaching, if they have not already reached, a decision on the final design for the Snowy River project.

Power Yields Compared

A comparison of costs as computed by those engaged on the preliminary work shows that the estimated capital cost of £A50,740,000 for the first part of the scheme would yield 720,000 kW—or £A70 a kW, excluding transmission costs. If the remaining third of the available water of the Snowy River were

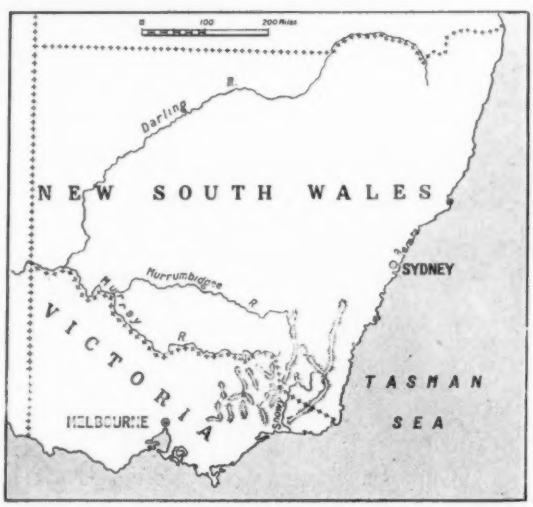
The source of the Snowy River in the Australian Alps; and (below) other rivers associated with the scheme

to be diverted to the Murray River, as suggested in plans that have been put forward by Victoria, the completed scheme then would produce 1,720,000 kW, and the estimated capital cost, again excluding transmission, would be £A100,690,000 or £A58 per kW. On the other hand, if it is decided to divert this water into the Murrumbidgee, with the other two thirds, the entire scheme would give substantially less hydro-electric power, and estimated capital outlay, without transmission costs, would be of the order of £A125 million, or £A80 per kW.

Bearing in mind the difference between these costs it is important to remember the main requirements of the two States most affected by the schemes. New South Wales is, primarily at all events, in need of further irrigation projects; Victoria wants hydro-electric power. Thus it comes about that these requirements, taken together, have posed in acute form the whole problem of harnessing the rivers of the entire Alps watershed, and developing the power now latent within them to the advantage of both States. The Murray, greatest river of the continent, along much of its 1,500 miles already sustains more than a million acres of rich settlements in New South Wales, Victoria and to a lesser extent South Australia. Similarly the Murrumbidgee, rather less than 1,000 miles from source to mouth, is the principal agency for supplying another broad belt of fertile country.

But the case of the far more turbulent Snowy, although it is only about 300 miles in length, places that river in a very different category. Here, many of the experts are persuaded, is an ideal combination of conditions for power development in a river which to-day races through the narrow gorges of the upper reaches to do nothing more useful finally than flood the extensive flats at the estuary. Bearing in mind also to-day's power restrictions, as well as requirements, it is a reproach that in this way something like 1,700,000 acre feet of water runs to the sea each year without having been harnessed to any useful work on its journey.

Victoria's experts back the claims of the Murray



Valley by about 50,000. For hydro-electric generation purposes it is claimed that the plan would permit power totalling 50,000 kW to be obtained. The cost of the scheme has been put at £A13 million, including hydro-electric works.

From Victoria the contention has been that the waters of the Snowy could be used much more productively to supplement those of the Murray. There are, it is true, certain similarities in the two proposals, but that of Victoria provides for a hydro-electric scheme that would generate 300,000 kW, against the 50,000 of the Murrumbidgee. Naturally the initial cost would be more, but in the long run the benefits would be greater for industry and the population generally.

Expanding Industry

It is when the all-important needs of industry are faced that power to replace waste comes most acutely into reckoning. In the years immediately ahead, in-

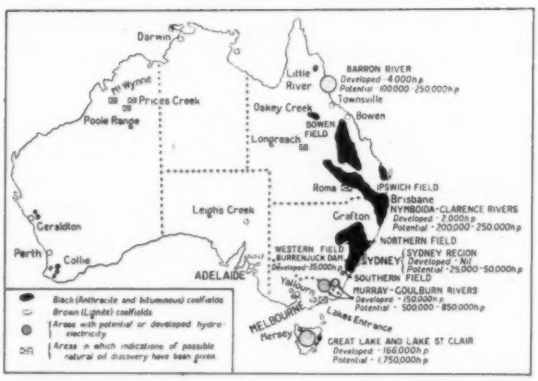
dustry in south-eastern Australia is destined to expand enormously. British, American and even continental European manufacturers have recognised since the close of the war that vast fields of opportunity have opened up in Australia, and many have established themselves in these naturally rich areas. Those in the best position to assess the future are virtually unanimous in the opinion that the next decade will bring a far more rapid extension of industry than any that has gone before. Markets are to-day awaiting exploitation in India, south-east Asia generally, Indonesia and the islands of the Pacific, forming together a colossal area containing nearly half the population of the world.

In New South Wales alone over 200 industries are now established, and official reports state that "not one of them has failed." The movement of population must also be taken into account. The Minister of Immigration, Mr. Arthur Calwell, has placed it on record in the last few weeks that newcomers are arriving at the rate of nearly 88,000 a year, which means that the population of Australia in ten years will be approaching the nine million mark, while (to quote the Minister) "prospects are brighter than ever that the younger generation of Australians to-day will see a population of 20 million."

Both the principal "population" States of New South Wales and Victoria, progressive though they

The Kiewa Scheme: Right — No. 3 Power Station. Below—A construction site in the valley

Artist's impression of the 289,000 kW Kiewa scheme. Underground work is indicated by imaginary cuts in the mountains. Right: Potential and developed power resources of Australia



may be, still are inadequately equipped to face this great industrial drive. At the moment the largest of the hydro-electric schemes in Australia is the Kiewa project, on the East Kiewa River in north-eastern Victoria. Its five power stations, indicated in the accompanying diagram, will ultimately have an installed capacity of 289,000 kW, and the total scheme will cost in the region of £A25 million. It is estimated that the additional water resources brought into operation under this scheme will be sufficient to permit electrical output of an average of 986 million kWh per annum. Storage at the Pretty and Rocky valleys will be increased respectively to 160,000 acre feet and 22,000 acre feet, and the underground tunnels will be driven through solid rock. Bold and comprehensive in conception, the engineering plan aims at full economic utilization of the power resources in the area around the Bogong High Plains in the Australian Alps. In fact the combination of high level storage sites and large snow-fed catchment areas may be described as almost unique in Australia. As the authors of the scheme point out, the great gain in capacity and output is due to the additional water that can be diverted from outside the Kiewa catchment itself into the upper storages, and the use of other water at much higher heads than was previously planned. Although actually a scheme for Victoria, it has now to be considered not only for its advantages to that State, but for its future benefit to Australia as a whole.

A "National" Link

The Kiewa scheme is probably the biggest in the Southern Hemisphere to-day, a factor which needs to be borne in mind when contemplating the even vaster project associated with the harnessing of the Snowy River, which would yield three times the capacity of all existing undertakings in Australia to-day. So far-reaching indeed are its possibilities that many lesser schemes throughout the three great eastern States of the continent will in all probability ultimately be linked with the Snowy River concept.

A special Government departmental committee has been examining plans for the development of additional water conservation and hydro-electric schemes in New South Wales and Queensland. Two major projects are under consideration—the provision of dams and irrigation schemes in the Burdekin River area of Queensland and the Clarence River area of New South Wales, both linked with the Snowy River project. Work on one of these subsidiary schemes, the Burdekin River, estimated to cost £A5 million to £A7 million, is to begin soon.

Finally, even defence problems come into the overall picture of progress through water power, for the future planning of defence arrangements, as well as those of industry and commerce, are in some measure dependent upon it. Australia has recognised the necessity for her becoming a main supply base in

Continued on page 132

Air Survey

By ROLT HAMMOND, A.M.I.C.E., A.C.G.I. The high precision of modern plotting machines enables air survey to be used for accurate mapping, which can be applied in the development of a hydro-electric scheme. Examples are given.

La haute précision des appareils modernes permet l'usage de la cartographie aérienne dans le développement des projets hydro-électriques. Des courbes de niveau jusqu'à l'échelle du 1250ème peuvent être levées avec un minimum de mesures au sol, avec une précision uniforme rarement accessible au levé terrestre. Très économe de temps, l'étude détaillée des photographies aériennes permet de déterminer le meilleur parcours des canalisations et les sites les mieux choisis pour les barrages et les stations génératrices. En outre, il n'est pas nécessaire de retourner sur le terrain pour vérifier les mesures.

Máquinas modernas de alta precisión permiten la preparación de mapas precisos, a base de fotografías aéreas, apropiados para el desarrollo de proyectos hidroeléctricos. Pueden prepararse planos de contorno hasta una escala de uno a 1.250 con el mínimo de control del personal de tierra, lográndose una precisión difícilmente igualada al efectuar un estudio terrestre corriente. Pueden efectuarse grandes economías de tiempo y puede determinarse el mejor recorrido para las tuberías y el sitio más apropriado para la presa y las centrales generadoras de fuerza motriz efectuando un estudio detallado de las fotografías aéreas. Además, las dimensiones pueden ser verificadas sin tener que visitar nuevamente el terreno.

AIR SURVEY has established itself as a reliable method of mapping and contouring, and it shows up to particular advantage when applied to the many problems associated with the development of hydro-electric power.

A reasonably accurate survey of all available catchment areas can be carried out at far greater speed than would be possible with ground reconnaissance, even under the most favourable conditions; moreover, sites for dams and reservoirs can be selected with reasonable certainty that they will be the most suitable for the purpose in view. Nevertheless, it must be stressed at the outset that accurate ground control is essential in all air survey work, a point emphasised by Hotine ("Surveying from Air Photographs," by M. Hotine, 1930), one of the pioneers of air survey. He wrote that the main object of geodetic control is "no less practical than the prevention of gaps in subsequent detail surveys, leading to the same area being mapped twice over on different sheets or being omitted altogether. The introduction of air survey emphasizes rather than reduces the necessity for such control."

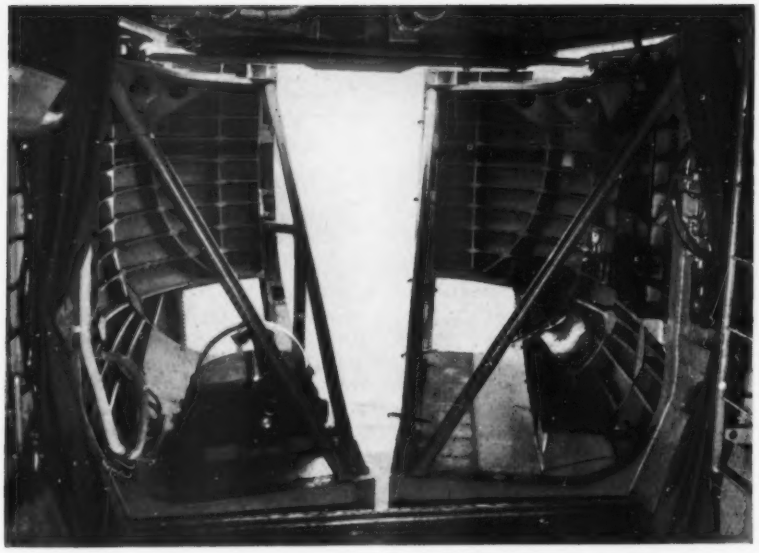
In the planning of a water power development, such ground control is essential because geological data are necessary, and these must be inter-related correctly in order to obtain a true picture of the general geological structure. Indeed, the latter will often determine the type of development adopted, and the more accurate that it is in the first instance, the more successful will be the final development of the whole project.

In Canada, where development of water power goes on apace, circumstances are peculiarly favourable to the use of air survey because of the thickly wooded nature of large tracts of country. In the Lac Seul development, for example, dams were constructed to raise the level of the water in the lake, the outline of the high-water contour being established on the vertical air photographs. Enough information was obtained thereby to enable the extent of forest which had to be cleared to be marked out, and the necessary tree felling programme to be planned.

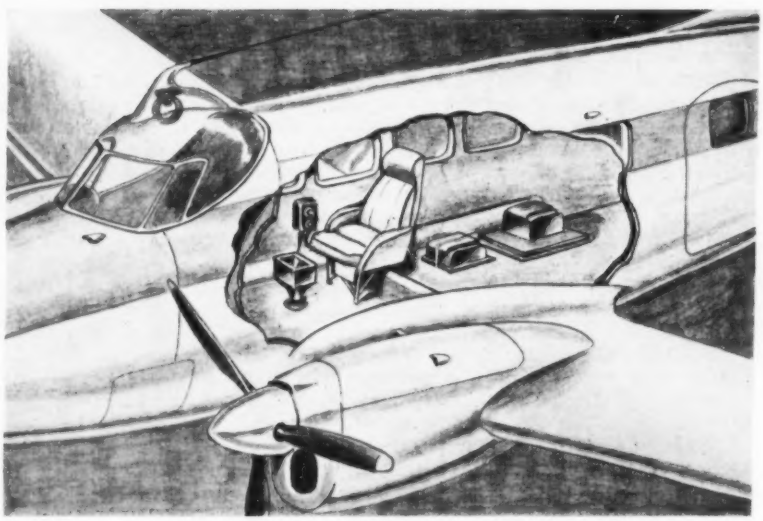
In the United States extensive and very successful air surveys of sites for dams and reservoirs have been carried out in recent years by air survey, one of the most outstanding achievements being a contoured map made from vertical air photographs of the Boulder Reservoir by the Fairchild Company. This was used for determining the rate of silting in Lake Mead and is a topographic map to a scale of 1 in 12,000 with contours at a vertical interval of 10 feet. It was produced from a Zeiss Stereoplanigraph from vertical air photographs. Control of levels and triangulation points were provided by the United States Coast and Geodetic Survey; contours being taken to a height of 170 feet above top water level of the reservoir.

This survey was particularly interesting and significant because it provided proof of the accuracy attainable by using air survey methods. After the sluice gates at Boulder Dam had been closed, the rising water line was photographed at contour intervals of 20 feet, and it was found that the contour lines on the photographs agreed closely with the photogrammetric contours determined by the original air survey. Another striking proof of the value of air survey was provided at the proposed site for a dam at San Gabriel for the Los Angeles County Flood Control District. In a letter to the Fairchild Company, Mr. E. C. Eaton, the chief engineer, wrote: "In checking your map we had available two independent contour maps . . . these maps were compiled from approximately 1,000 points per acre, which were established by precise triangulation and levelling. The quantities computed . . . from your map varied less than one-tenth of one per cent. from the mean of the other two maps, based on estimated excavation."

To-day the African Continent holds enormous possibilities for development—in the production of food, steel, gold, minerals and many basic raw materials.



graphic Surveying in Relation to Road Engineering in Highly-Developed Countries" by B. F. J. Bradbeer, M.C., and Professor C. A. Hart, M.Sc., A.M.I.C.E. — Road Paper No. 26, Inst.C.E., 9/3/48), who referred to the work at Purdue University, U.S.A., where complete soil maps have been made of the State of Indiana. From these it was possible to determine whether the soil or rocks in a particular area were of an igneous, metamorphic, or sedimentary origin, and to subdivide those groups into smaller groups, so that if a rock were sedimentary it could be determined whether it was sandstone, limestone or shale. The type of rock was determined from an examina-



Above: Bristol aircraft adapted for air survey work. Right: Cut-away view of the De Havilland Dove survey aircraft

It can make an increasing contribution to the prosperity of the British Commonwealth, but such large scale production depends ultimately upon the availability of abundant and cheap electric power. Latent water power resources should therefore be developed with the utmost speed. Great interest attaches to the remarkable work already done by the Aircraft Operating Company of Africa, which carried out an air survey in Northern Rhodesia for a complete hydro-electric development. By ground survey methods, many months of tedious and costly reconnaissance would have been necessary, but all this was eliminated because the best route for pipe lines and the most suitable sites for dam and power station could be determined by a detailed study of air photographs.

Having selected the route, ground surveyors merely took levels and ran a traverse along it. Moreover, only two days' study of air photographs was necessary to determine the channel for the Lunsenfwa scheme.

An air survey for a water power development will provide engineers and designers with a thoroughly dependable foundation upon which they can work, and upon which they can base their reports and contentions. The photographs are extremely valuable for the information they provide about the geological structure, a point recently emphasised by F. N. Sparkes (Contribution to the discussion on "Photo-

tion of the type of vegetation, by the width and course of rivers, by the slope of gully walls, and by similar factors. Furthermore, the presence of glacial drifts, gravel eskers, and deposits of other materials suitable for constructional purposes could be recognised from air photographs.

Information provided by air photographs depends upon weather conditions, and the scale and angle at which they are taken. Although oblique photographs give a more natural view of the country, stereoscopic pairs of vertical air photographs are necessary for contouring and precise technical information.

In a recent survey carried out by the Air Survey Co. Ltd., in the Middle East, the total area involved was 1,970 square kilometres; most of this area was mapped on a scale of 1 : 5,000 with a contour interval of two metres. In addition, an area surrounding a large town was mapped on a scale of 1 : 2,500, while a large river valley was mapped at 1 : 10,000 with a

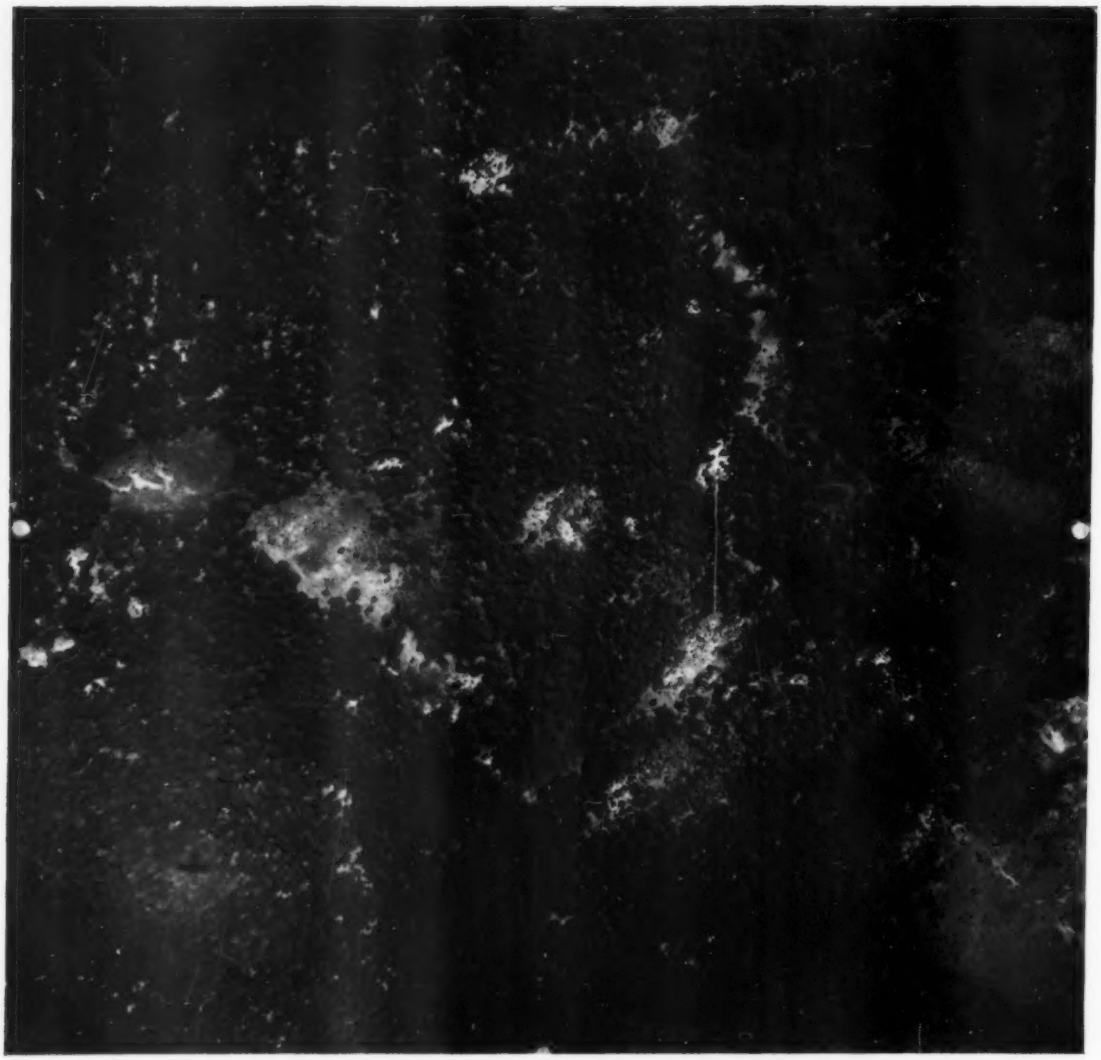
Geological formations in Middle East. Scale 1/21,120

general contour interval of five metres. A Williamson Eagle IX camera was employed, with a Ross wide angle survey lens of 6 inch focal length. This camera was carried in an Oxford aircraft flown at a ground clearance of 6,000 feet for the 1 : 5,000 mapping and at 10,000 feet for the 1 : 10,000 mapping. Since the mean ground elevations were between 1,000 feet and 2,000 feet above sea level, the actual flying heights were 7,200 to 7,500 feet in one case and 11,000 feet in the other.

A ground survey party of five surveyors operated in the field for about eight months, and as a very good triangulation already existed in the area, the horizontal control merely involved trigonometrical fixation of the required points from the existing triangulation points. Climatic difficulties were considerable, and during the worst period operations started about 4 a.m. and all theodolite work had to be finished by 7.30 a.m., because it was impossible to take sights through the heat haze.

The specification for vertical control required an accuracy of the order of plus or minus one foot over 100 kilometres, and to ensure this a line of precise levels was run through the centre of the work from east to west to form a long backbone for the survey. At right angles to this control and at intervals of about every 10 kilometres, lines of precise levels were run across the length of the photography. The whole of this work was done with double staffs using Zeiss Geodetic levels, and a specified accuracy of 10 centimetres in 10 kilometres was maintained.

A total period of 13 months elapsed from departure of the expedition oversea to the printing of the last map sheet. It is claimed that the accuracy attained compares very favourably with what could have been expected from any form of ground survey over the same area. When this consideration is taken into account with the tremendous time saving achieved, the true value of air survey can be readily appreciated. Another outstanding recent air survey was carried out



Mixed forest of oak and chestnut. Scale 1/7,000

during the winter of 1946—7 for the Anglo-Iranian Oil Co. Ltd., in Iran by Hunting Aerosurveys, Ltd.; this survey was mainly concerned with the geology of the country, and to help future development work in the areas concerned, including refinery construction and the planning of new housing estates at Abadan. Topographical maps in the oilfields areas were made to a scale of 1 : 21,120 and plans of the refinery area to a scale of 1 : 2,400. The survey party consisted of a chief pilot, manager, chief air photographer, a reserve air photographer, a photo processor and a processing assistant. They left this country in December, 1946, and returned at the end of May, 1947.

The survey aircraft used for this work was a standard Bristol Freighter (Fig. 1); the Williamson Ordnance Survey camera was installed on the port door, and the control apparatus for the camera on the starboard door. In order to provide the camera with as wide a range as possible (and to conserve film) the aircraft flew over the oilfields at a height of 22,000 feet; oxygen apparatus was installed, and an extra 350 gallon fuel tank gave increased range. The camera had a six inch wide angle lens and was loaded with a spool of film giving 500 exposures, each measuring 9 inches by 9 inches.

Since the requirements of the surveyor vary widely, even when considering the specialized application to water power projects, no one type of aircraft can meet all the surveyor's needs. Fig. 2 shows a survey model of the de Havilland Dove, powered by two Gypsy Queen 70 engines driving de Havilland constant-speed quick feathering propellers. This is a convertible version of the standard eight-passenger Dove, interchange of survey equipment with the full set of passenger seats being simply and quickly effected. All seats are removed, except the second seat on the starboard side, which is used by the camera operator. At the photographer's feet is the drift sight; immediately behind him is stowed a spare magazine, which is strapped to the floor. The camera shown in the sketch,

aft of the spare magazine, is a Williamson Ordnance Survey Camera Mark 3; the magazine is driven by a separate motor, and its capacity of 500 9 inch by 9 inch exposures will usually permit a full day's work to be carried out without changing magazines.

When flying at high altitudes direct speech may be difficult between camera operator and pilot when oxygen has to be used, and an extension of the standard Dove intercommunication system can be provided; a microphone socket is mounted by the camera control box. A signal lamp fitted in front of the pilot is connected to the camera control box and gives warning five seconds before a photograph is to be taken. The pilot is thereby relieved of the continuous concentration of maintaining level flight between exposures.

Air survey is not considered to be suitable for scales greater than 1 : 1,000, but recently a large scale survey was carried out by Hunting Aerosurveys, Ltd., using air photographs combined with ground control survey at Folkestone Warren, where an area of cliffs three miles long and half a mile wide was mapped to a scale of 1 : 1,250, with contours at 5 foot vertical intervals. Here the cliffs vary in height almost from sea level to 400 feet at the top; the precipitous cliff formation and gradual coast erosion had caused several land slides and seriously endangered the railway. This is the kind of problem that might confront an engineer on a water power development.

The extremely difficult terrain ruled out the possibility of a ground survey, and only from the air was it possible to produce a map of the required degree of accuracy in the time demanded by the urgency of the work. Planimetric control was taken from the Ordnance Survey 1 : 2,500 scale sheets, supplemented by levels supplied by a ground party. The drawing of plans from air photographs was carried out in the Wild A.5 stereoplotting machine at a scale of 1 : 1,250 with contours at 5 foot intervals.

This example of large scale air survey forms a fitting tailpiece to this short review, because it serves to emphasise the fact that the very high precision of modern plotting machines enables air survey to be used for accurate mapping. Contour plans up to this scale of 1 : 1,250 can be produced with a minimum of ground control, and to a uniform accuracy seldom attainable by ground methods. Moreover, not only is an enormous saving of time effected, but measurements taken from air photographs may be checked without revisiting the area, and all details may be studied in sharp relief by examining pairs of photographs in a stereoscope.

220 kV Impregnated Pressure Cable

AN underground cable designed for continuous 200 MVA duty at a service voltage of 220 kV has been manufactured by British Insulated Callender's Cables and is being installed in France in conjunction with the French cable firm, *Trefileries et Laminoirs du Havre*. The cable will be laid in the grounds of the Clamart Laboratories of *Electricite de France*, and is to be connected to the 220 kV grid network for long term field testing. It comprises a 110 yard (100 metre) 3-phase loop of single core cable with sealing ends, joints and gas control equipment.

Design and Manufacture

The cable is of the impregnated pressure type developed by B.I.C.C. and the conductor consists of 91/.104 inch (91/2.64 mm.) tinned copper wires stranded in circular form with a cross section of 0.775 sq. inch (500 sq. mm.). The mass impregnated paper dielectric, which includes the usual outer screen of metallised paper, involved simultaneous application of more than 200 paper layers. Copper woven fabric tape is applied over the completed dielectric to protect the metallised paper screen and to ensure positive contact with the lead sheath. As in standard I.P. practice only one lead sheath is used; this is extruded with a small clearance to assist gas charging. It is covered with special cable reinforcement tapes applied in such a manner that adequate strength is given to the lead against both the longitudinal and circumferential mechanical stresses that are set up when the cable is charged with nitrogen gas at 200 lbs./sq. inch (14 kG/sq. cm.) pressure. The cable is finally served with a special anti-corrosion protection of alternate layers of rubber and bitumen impregnated tapes.

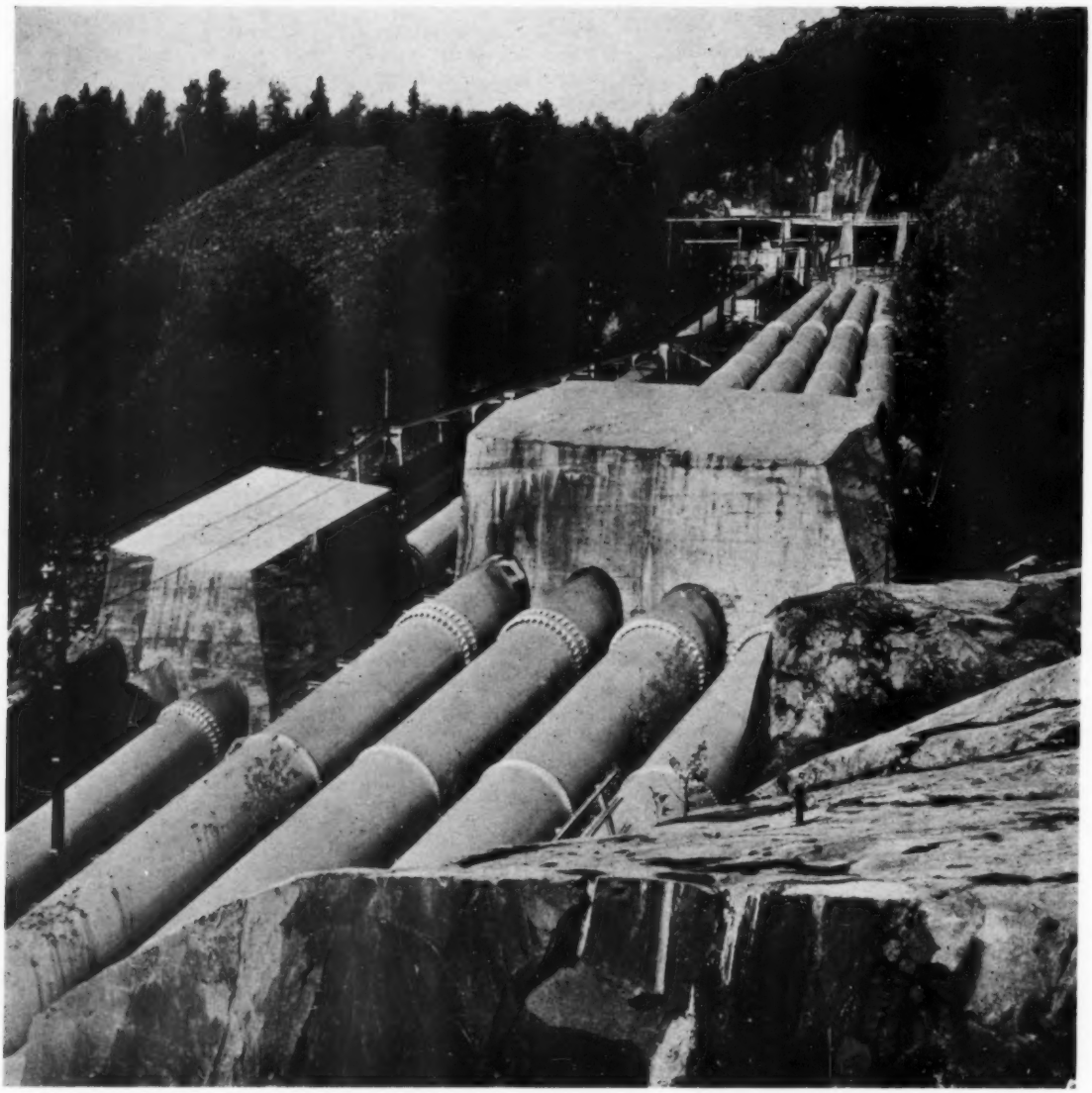
Sealing Ends and Joints

The cable was manufactured at the Erith Works of B.I.C.C. The overall diameter of the completed cable is 3.774 inches (9.6 cm.). The weight per yard is 51.3 lbs. (25.4 kG/metre).

A feature of the design is the adoption of semi-conducting glaze on the sealing end porcelain to equalise the end-to-end stress. This is the first time that stabilising glaze has been used for a voltage of 220 kV. Cast plumbs are used for hermetically sealing the main joint sleeve to the cable sheath and for anchoring the cable reinforcement tapes. An outer sleeve of copper for the main pressure housing and an inner sleeve of lead, plumbed at each end to the cable sheaths, provide a continuous pressure-skin across the joint and a means of pressure-testing the joint before it is finally put into service.

A 15 yards (14 metres) sample length of cable complete with one joint and two sealing ends has been given a special series of high voltage tests in Great Britain. The cable and accessories have been subjected to a voltage of 350 kV for a total period of over 24 hours. A series of impulse tests will be applied to the sample consisting of 20 impulses at 1,080 kV peak, 10 consecutive impulses of each polarity. Finally, the surge breakdown voltage of the installation will be ascertained by raising the surge voltage until breakdown or flashover occurs.

In addition to these tests a 110 yard (100 metre) 3-phase feeder will be installed at Clamart and connected to the 220 kV French grid for long term test. The installation is required to withstand current overloads up to 80 *per cent.* for periods of time up to half an hour, the overload trial starting from full load equilibrium conditions. At a later date, full details will be published of the results of the English and French cable tests, which are in connection with the intended use of this type of cable on the 220 kV network in France



Great pipelines, anchored by concrete blocks, running down the hillside from Aasgaard, Norway, to the power station below.

Power Pipe Lines

By GEORGE G. ROBB (Stewarts and Lloyds). General discussion; water-carrying capacity and calculation of pipe thicknesses; methods of jointing, safety factor, and other relevant information.

Après une étude d'ensemble des grosses conduites d'eau dans les installations hydro-électriques, l'auteur examine leur capacité de transport et la manière dont on évalue leur épaisseur. Il propose une formule simplifiée, dérivée de la théorie "Tension-Energie" de Haigh. Les types usuels de raccord sont représentés et l'auteur mentionne la nécessité d'un coefficient de sécurité approprié sur toute la longueur des canalisations. L'expérience a montré qu'un profil et un plan de parcours exacts sont essentiels à la détermination de l'angle de toutes les courbes et de la longueur des éléments entre elles.

Después de una discusión general de las tuberías de descarga de agua para instalaciones hidroeléctricas, el autor estudia su capacidad de conducción y los métodos para calcular el espesor de los tubos. Proporciona una fórmula simplificada desarrollada a base de la Teoría de Esfuerzo-Energía de Haigh. Se ilustran uniones de tipos corrientes y hace referencia al factor de seguridad para tuberías en la totalidad de su longitud. La experiencia ha demostrado que es esencial poder contar con un perfil y planta detallados del recorrido, con el objeto de determinar el ángulo de todos los codos y las longitudes entre codos.

HYDRO-ELECTRIC installations depend primarily on there being available at a suitable level a practically continuous supply of water, secured generally by ample storage capacity in the form of lakes or reservoirs, and their development involves several major considerations, all of which can vary within wide limits for different schemes. The general subject of power pipe line (or penstock) only will be discussed in this article.

In any scheme the size and route of the pipe line, or pipe lines, must be considered in conjunction with the quantity of water available, and the sites suitable for reservoir and power house. Frequently, laid at a small gradient, there may require to be an initial stretch of open channel, tunnel, or pipe line leading to the forebay, from which begins the power pipe line proper.

Usually hydro-electric power pipe lines — of necessity—are installed in rugged country, and light weight consistent with strength is a deciding factor. For this reason, the pipes are generally of steel, and, as the majority of these pipe lines are of fairly large diameter (say, 2 feet or more) some form of longitudinal joint in the pipes is necessary. This longitudinal joint is most frequently welded; riveting is an alternative but riveted pipes have the disadvantage, due to rivet heads, of incurring high friction losses. Depending on the diameter of the pipe, and on the width of plate obtainable from the steel works, welded pipes may have either one or two longitudinal welds.

Pipe lengths vary according to the lengths and the weights that can be transported and installed at site; 20 to 25 feet represents a fairly common range within which welded pipes are supplied for hydro-electric installations, but longer and shorter lengths can be got when desired.

For a given set of conditions—quantity of water, length of power pipe line and gradient—it may be possible to adopt one of several sizes of pipe within appreciably wide limits. The larger the diameter, the smaller is the loss of head by friction and the greater is the power developed, but the law of diminishing return operates and it becomes a matter for the responsible engineers or the purchasing body, with their full knowledge of requirements, of the use that can be made of surplus energy generated, and of the provision necessary for future development, to decide the size of main, or mains, that should be installed. It may also be necessary to consider whether circumstances warrant the development of the whole water power resources at one time, or whether the development should be done in stages, spread over a number of years. To assist in deciding these points it may be desirable to get provisional estimates from the pipe manufacturers for two or more sizes of pipe line, and this leads to consideration of the carrying capacity of different sizes of pipes.

Water Carrying Capacity

There are a large number of formulæ for flow of water, but a great degree of refinement in computing probable friction loss in a hydro-electric power pipe line is generally unwarranted, and any of the better known formulæ (and tables) can be used.

Water flow formulæ and tables, as a rule, cover plain straight pipes, and allowances have to be made for entrance and exit losses, and for the effect of joints, change of diameter, bends and branches. In addition, it is common practice to add to the calculated friction loss a *percentage* to cover uncertainties and contingencies—usually from five to ten *per cent.*

Before deciding the diameter of a water power pipe line an investigation somewhat on the following lines is desirable.

These figures show how return tends to diminish with increased capital expenditure.

In this example: 175 W.H.P. is got from £3,500 additional capital expenditure on pipes between 31″ o.d. and 34″ o.d.; while only 45 W.H.P. is got from

EXAMPLE

Power to be developed (say) . .	8,000 water horse power (W.H.P.).
Quantity of water available (say) .	70 cusecs = 26,250 galls./min.
Length of line (say)	3,000 feet.
Static head (say)	1,050 feet.
Pipes	Welded steel.

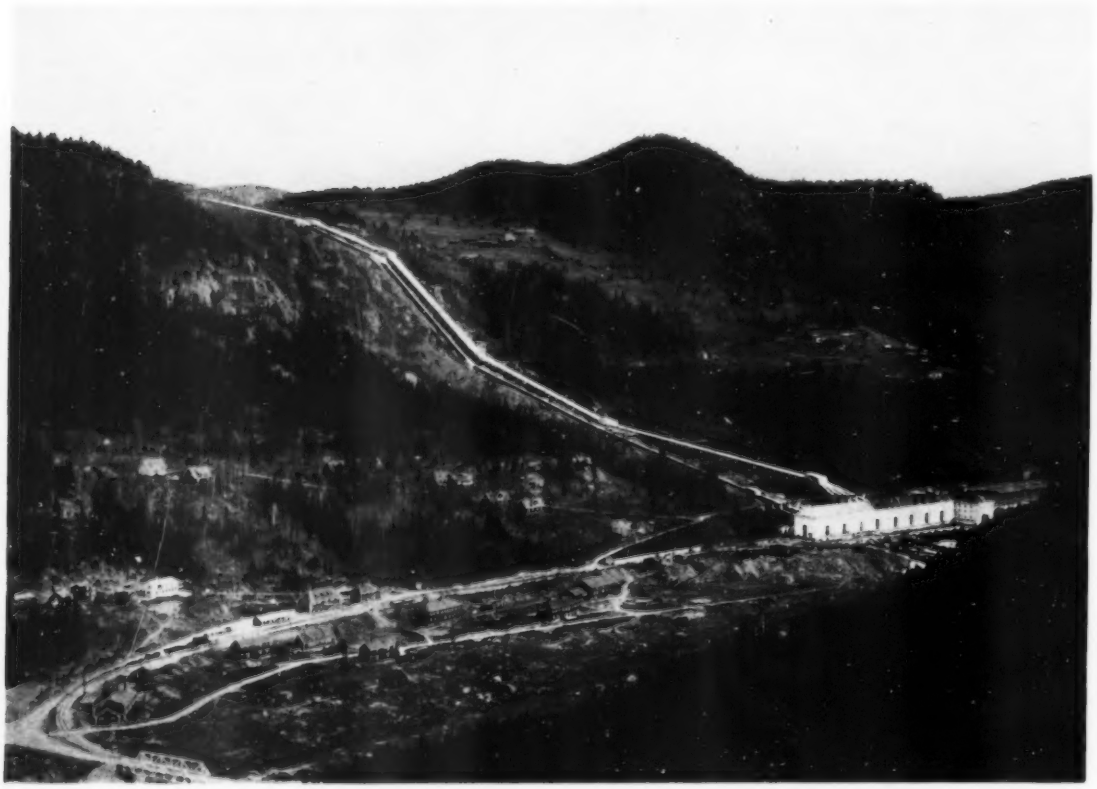
Possible diameters of pipe line (outside diameters) (ins.)	46	41	37	34	31
Approx. velocity of flow (ft./sec.)	6½	8	10	12	14½
Approx. rate of friction loss	1/375	1/225	1/130	1/85	1/55
Approx. head lost by friction (ft.)	8	13.5	23	35.5	55
Other losses and contingencies (ft.)	2	2.5	3	4.5	7
Total friction loss (ft.)	10	16	26	40	62
Nett available head (ft.)	1,040	1,034	1,024	1,010	988
Calculated W.H.P. obtainable	8,270	8,225	8,145	8,035	7,860
Cost difference of pipe line between sizes, allowing for civil engineering work and erection in Great Britain, might be about		£8,000	£5,500	£4,000	£3,500
Increased W.H.P. obtainable		45	80	110	175

£8,000 additional capital expenditure on pipes between 41″ o.d. and 46″ o.d.

In deciding the size of pipe line to be installed much will depend on circumstances, such as the value of the extra power produced and the annual return obtainable on the increased capital expenditure incurred on pipes.

While velocities around 10 to 12 feet per second are fairly common in hydro-electric power pipe lines, speeds up to about 20 feet per second are not unknown. In hydro-electric pipe lines it is common practice to have a larger diameter at the top than at

Pipe lines follow the contour of the ground to the power station (Nore 1). An artificial lake now fills this valley in Norway



the bottom; say, the top third of the pipe line about 3 to 6 in. larger, and the bottom third about 3 to 6 in. smaller, than the middle section. The number of sizes may, of course, be two, or more than three, depending on circumstances. One advantage gained by making the diameter of the bottom section of the pipe line smaller than the required average diameter is that a smaller maximum thickness for maximum pressure can be adopted than would otherwise be possible. Increased loss of head in this smaller diameter section is counterbalanced by reduced loss of head in the larger diameter top section. Apart from these considerations, a uniform diameter main may be installed if desired. In some schemes it may be economic to instal a single large diameter pipe from the forebay to the position where the design head necessitates maximum convenient manufacturing thickness, then bifurcate into two smaller lines and continue with these to the power house.

After fixing preliminarily the size of main desired, reference should be made to lists of standard outside diameters and the nearest standard size, if possible, should be adopted. The *outside* diameter of the pipes within each section—if the line is of two or more sections—should be the same. This is a convenience in production and in jointing the pipes at site.

In a water power pipe line the pressure increases gradually from the upper to the lower end, and, in consequence, thicknesses increase correspondingly. It is fairly common practice to have thicknesses in exact sixteenths of an inch, with a $\frac{1}{16}$ in. step between each thickness. There is no universally accepted formula for the calculation of pipe thicknesses; but the following which, in effect, is a simplification of that derived from the Haigh Strain-Energy theory can be used with confidence:

$$t = \frac{PDF}{2Se} + k + c \quad \text{or} \quad P = \frac{2Se\,(t-k-c)}{DF}$$

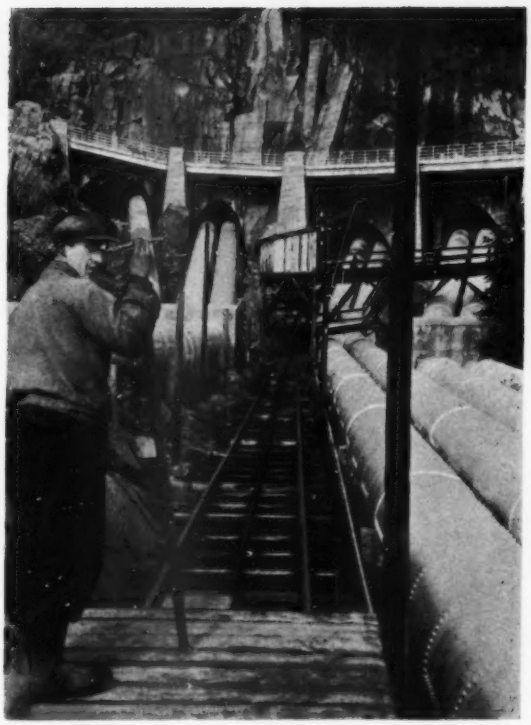
where P = design pressure in lb. per sq. in.
D = outside diameter of pipe in inches.
S = minimum ultimate tensile strength (U.T.S.) lb. per sq. in.
F = factor of safety on minimum U.T.S. (4 is a figure frequently adopted—departure from this is usually upward, not downward).
e = minimum efficiency of weld.
t = nominal or "plate" thickness, ins.
k = minus tolerance on "t" required by manufacturer.
c = constant which depends on circumstances and the views of the engineer (usually it varies from 0 to $\frac{1}{16}$ in.).

Steel for welded pipes used for hydro-electric power pipe lines usually has an ultimate tensile strength of about 26/30 tons per square inch.

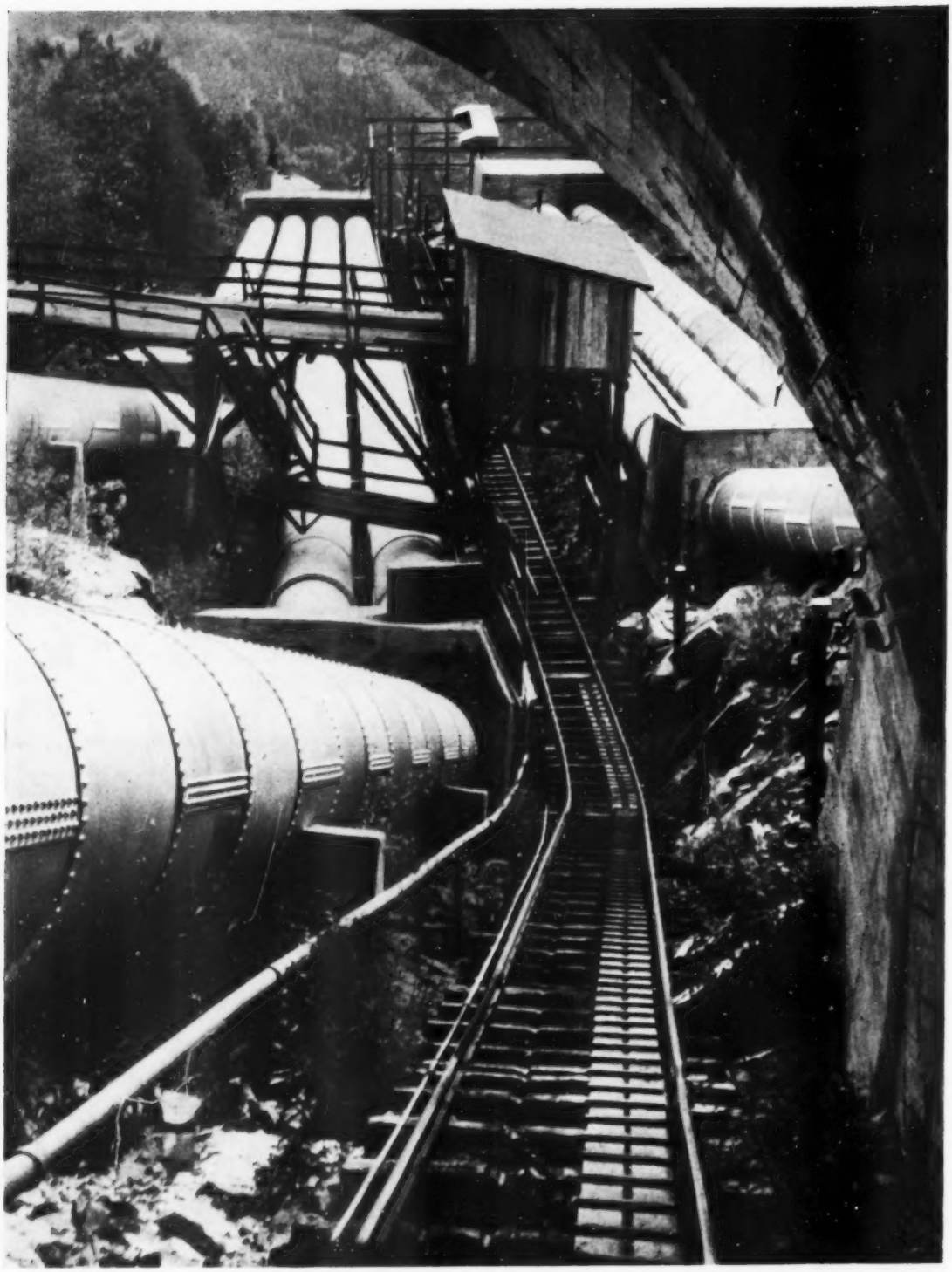
Design pressure "P" for all positions throughout the line should be decided by the engineer, or consultant, and should allow for such pressure rise as he considers necessary, following the decisions taken in regard to the equipment at the lower end of the pipe line to control pressure rise.

"F" may be regarded as a true factor of safety, since allowance has been made for all unfavourable variations.

Some authorities suggest that the factor of safety should be based on the "yield strength," but as the minimum yield strength of ordinary mild steel is around 50 *per cent.* of the U.T.S. there does not appear to be much point in relating the factor of



The valve chamber is excavated in the mountain.—Here the pipes are seen leaving it and (below) running to the station



A view from the valve chamber exit. Workmen travel by trolley up the rail track to Aasgaard

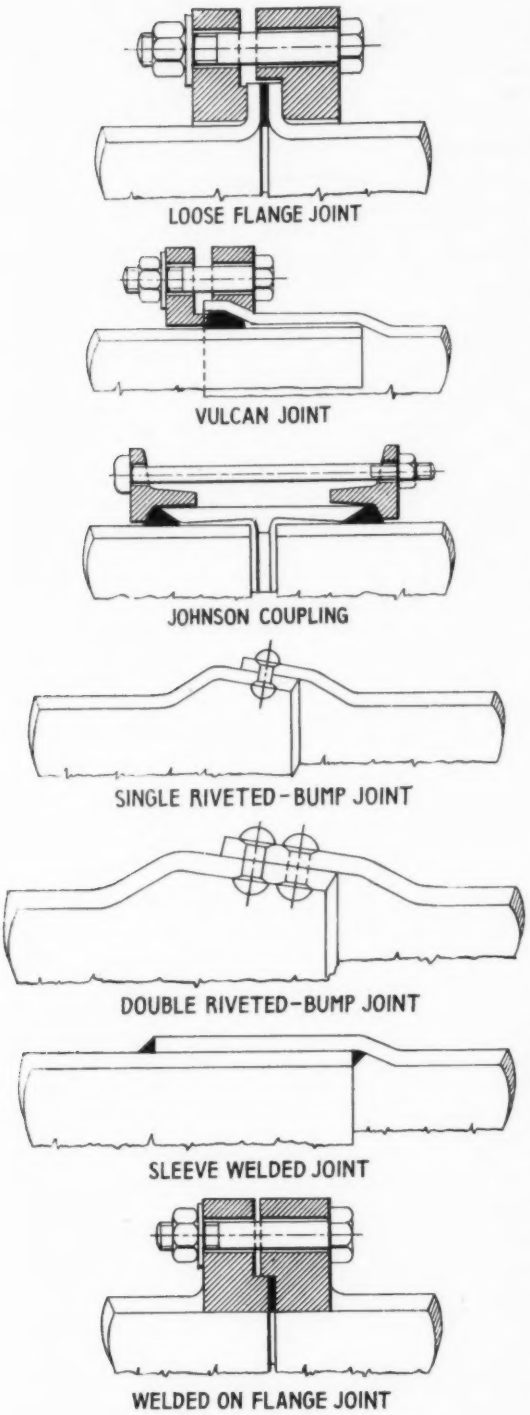


Fig. 1. Essential features of some common types of pipe joints

safety to the yield instead of to the ultimate. The writer is aware of one installation having been designed on the basis of a formula generally as given, but " F " taken as 1.3 on minimum yield; in this case the question of pressure rise was considered in much detail by the engineer, and the design pressure fixed appreciably higher than the static head.

It is usual to calculate the pressure for which several exact sixteenths of an inch thicknesses of a pipe of the selected outside diameter are suitable, and then to fix on the profile the change points between thicknesses corresponding to the *design* pressures which have been fixed by the engineer, or consultant, for the pipe line as a whole.

There are certain minimum plate thicknesses of pipes below which it is undesirable to go, and the following information is indicative of British practice:

- 1/4 in. minimum for pipes 24 in. diameter.
- 5/16 in. minimum for pipes over 24 in. to 36 in. diameter.
- 3/8 in. minimum for pipes over 36 in. to 48 in. diameter.
- 7/16 in. minimum for pipes over 48 in. to 54 in. diameter.
- 1/2 in. minimum for pipes over 54 in. to 60 in. diameter.
- 9/16 in. minimum for pipes over 60 in. to 66 in. diameter.
- 5/8 in. minimum for pipes over 66 in. to 72 in. diameter.

These minimum thicknesses have been fixed not only to suit manufacture and handling, but also to allow a sufficient margin against collapse should a pipe line accidentally be subjected to a vacuum. Cases have occurred where, due to a mishap, vacuum has been created in the upper parts of a pipe line, the pipe line has been too thin to withstand the external atmospheric pressure, and has collapsed.

The external collapsing pressure of a pipe of small t/D ratio can be calculated from the formula:

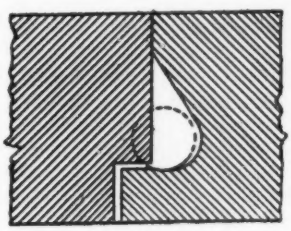
$$P = \frac{610(Y)^3}{(Y - 10{,}250)^2} \left(\frac{t}{D}\right)^3$$

Where P = external collapsing pressure, lb. per sq. in.
Y = minimum yield strength, lb. per sq. in.
t = nominal or plate thickness (ins.).
D = outside diameter of pipe (ins.).

There are a fairly large number of different forms of joints available for hydro-electric pipe lines, the majority of which are installed above ground. The more common types of joints are shown in Fig. 1. The details given, it is hoped, will make clear the essential features of the joints. The type of joint selected usually depends on the site conditions and the labour and supervision available for assembly.

Past practice for power pipe lines installed above ground has generally favoured the introduction of an expansion joint, of the stuffing box type, between each pair of adjacent anchors and its insertion just below the upstream anchor—although the position can be varied to suit the views of the engineer in charge. Movement at the expansion joint is usually small and such that in many cases the expansion joint could, from the point of view of movement in service, possibly be dispensed with altogether; but it has the undoubted advantage of providing by its sleeve a means of facilitating assembly, and allowing for slight inaccuracies that may occur in determining beforehand the exact lengths (centre to centre) of bends.

With the inclusion of an expansion joint between each pair of anchors, the joints in the line, with the exception of a few at or near the power house, are not subjected to full end loads and consequently



A high-pressure leak-proof joint

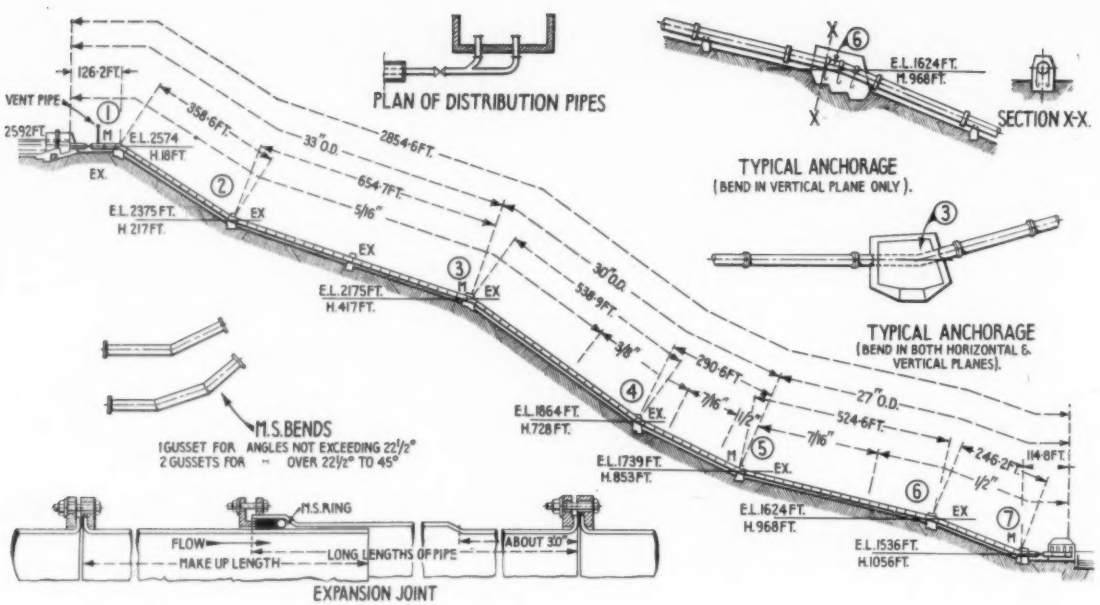


Fig. 3. An accurate profile and plan of the pipe line route is essential in order to determine all angles

can be made lighter if desired and yet be sufficiently strong to ensure leak tightness.

Near the power house and below the main anchor, joints generally require to be designed to withstand the full end load, and such joints are usually of the conventional flange type, with bolts and flange thicknesses of adequate strength. For such joints where the pressure is high—say, possibly over 500 lb. per sq. in.—it is common practice to effect leak tightness by means of a round rubber or gutta percha ring, with a joint facing somewhat similar to that illustrated in Fig. 2.

Bends and branch pipes (or tees) can, in many cases, be formed from mild steel pipe. The alternative is cast steel fittings. Mild steel bends are usually of the gusseted type (see Fig. 2).

1 gusset for angles up to 22½°.
2 gussets for angles over 22½° up to 45°.
3 gussets for angles over 45° up to 90°.

They can be formed generally of such length centre to ends as may be required to permit the joints on the ends of the bend to be outside the anchor block. Steel castings can be used but these will be of limited length, possibly considerably less than the length necessary for the anchor blocks, resulting in the end joints being embedded in the concrete, unless the concrete is " stepped " to give access to the joints.

An accurate profile and plan of the route is essential in order to determine for production the angle of all bends and the lengths between bends. It is usual to combine horizontal and vertical deviations in one bend, and so reduce the number of bends.

To provide the required factor of safety branch pipes (or tees) may be made thicker than the adjoining straight pipes, or bends; or, alternatively, they may have added reinforcement around the branch junction and flat surfaces.*

It is fairly common practice, particularly on power pipe lines above ground, and over about 20 in. diameter, to provide a number of short manhole branches, to permit access for examining and reconditioning the inside surface as may be necessary.

Pipes are generally supplied coated inside and outside with bituminous solution, and are further coated with a similar solution externally and, if possible, internally after erection.

Fig. 3 gives a general impression of what is necessary to complete the pipe details for a hydro-electric pipe line. In addition to this, a schedule of materials, with all parts numbered, is necessary. For field use a profile drawing folded in concertina form (pocket size), with all pipe line details, should also be provided for the help and guidance of those in charge of erection.

The supporting and anchoring of a hydro-electric power pipe line above ground require very careful consideration. They raise problems which can only be satisfactorily dealt with by the civil engineers who are conversant with all the site conditions, including the permissible ground pressure at different parts. Sometimes a support is placed under each pipe length near the joint; but a support underneath each alternate pipe length may be adopted, depending on the joint used and the Modulus of Section of the pipe relative to the bending moment imposed. These problems are, however, outside the scope of this article, but the forces which do occur at bends and other points are dealt with in many books on hydro-electric engineering.

**For a detailed study of this subject reference should be made to " Reinforcement of Branch Pieces " by J. S. B'air, D.Sc., M.I.Mech.E., published in " Engineering," July to December, 1946.*

Hydro Power in Western Germany

By FRED. K. McQUEARY and WOLFGANG LEPPIN. Present state of development of hydro plant in relation to the total electricity supply in Western Germany; the effect of Allied bombing on installed plant; and plans for early extensions to hydro capacity.

Cet article traite de la contribution de la houille blanche à la production totale d'électricité en Allemagne Occidentale. Il montre l'actuelle mise en valeur, les effets de la guerre sur les installations existantes et les plans d'exploitation dans l'avenir. Il souligne la nécessité de l'intégration européenne du réseau de force et l'auteur ajoute, à cet égard, que si les lignes de transport de 400 kV prévues sont installées le réseau électrique européen en sera très amélioré et la houille blanche jouera dans l'avenir un rôle plus important encore.

Este artículo versa sobre la relación de la fuerza hidroeléctrica en los suministros totales de electricidad en el Oeste de Alemania. Discute su estado de desarrollo actual, los efectos de la guerra sobre las instalaciones hidroeléctricas ya existentes y los planes para su desarrollo. Hace resaltar la necesidad de un sistema integrado de energía en los Estados Europeos y el autor añade que si, tal como se lleva propuesto, se instalaran líneas de transmisión de 400 kilovatios, el sistema de la red sería grandemente reforzado y la energía hidroeléctrica desempeñaría un papel todavía más importante en el porvenir.

WESTERN Germany is supplied with electric power through a highly developed and integrated 220 kV and 110 kV transmission grid. Feeding into this grid are the large thermal generating stations situated chiefly on or near the coal and lignite fields of the north, and the hydro stations of the more mountainous regions of the south. A few key thermal stations are, of necessity, far removed from the coal deposits and are located strategically within load centres outside the industrial Ruhr region.

This article will concern itself with the contribution of hydro power to Western Germany's total electricity supply. It will attempt to show the present state of development, the effect of the war on installed hydro capacity and something of the plans for further development, as well as water power's importance in Western Germany—this crossroads of electric power lines which will and should link the countries of Western Europe for their mutual and general benefit.

Western Germany's water power sources fall into two main groups. The Bavarian Alps and the upper Bavarian tablelands yield their waters, through numerous tributaries, to the Danube River and provide one appreciable power source. The large basins of the Black Forest region of South Baden drain through several rivers and streams into the upper Rhine and provide the second general source. In these two areas, then, are the principal water power plants; and here, too, more will be developed. There are numerous smaller and run-of-river stations along the Neckar River in Wuerttemberg and North Baden, along the Main in Hesse and Bavaria, and a very few in North Rhine/Westphalia; but in these sections development has just about reached its maximum.

Let us consider the first of the two main groups: Bavaria. Electrical consumption is provided chiefly by Bavaria's hydro sources as seen in the following comparative table.

GENERATION IN BAVARIA

(Mill. kWh)

	1936	1947	1948
CONSUMPTION	1,657	2,972	3,624
TOTAL GENERATION ...	1,750	3,283	3,998
HYDRO GENERATION ...	1,630	2,674	3,316

Whereas the Danube, the great west-east river, is at present only partially developed and furnishes the motive power for only one Bavarian hydro station, Kaschlet near Passau, its tributaries running from south to north are highly developed. First of them, in western Bavaria, is the Iller River on which are situated a great number of small stream-operated stations with a total capacity of 43 MW. On this river is located the Steinbach station, the first of the widely publicized hydro power stations, constructed in 1938. All of this station is wholly under water—it is installed in a tunnel extending beneath the river. Water is admitted through controlled butterfly valves and drives simple impeller turbines, with the generator literally installed around the turbines. A picture of this is shown in Fig. 1. This was one of the Arno Fischer stations, many of which were planned during the Nazi regime. It was claimed that their construction expense was considerably less than in more conventional stations and that such stations could not be seen from the air and would not therefore become bombing targets. Most German engineers now agree that both arguments were completely fallacious.

The River Lech is much more exploited and its stations are divided into two groups, the Upper and

Fig. 1. Turbine surrounded by Generator at Stinbach Station

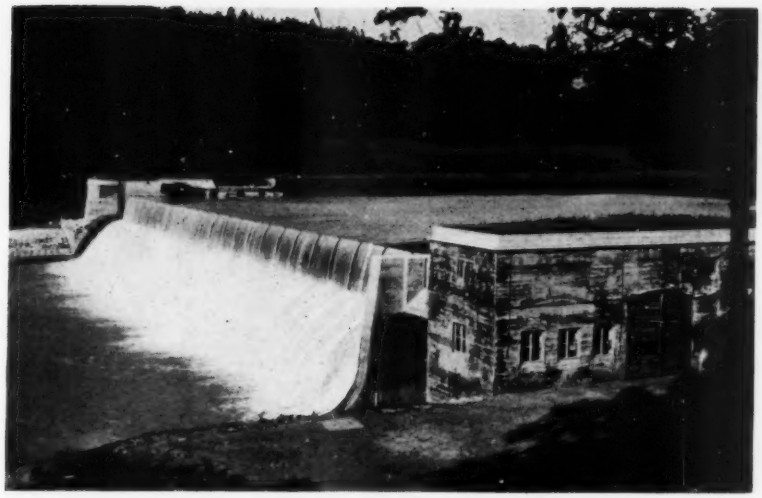
the Lower Lech groups. The Upper Lech is the more interesting. Near the Austrian frontier at Rosshaupten a reservoir of 168 M.m³ was planned which would equalize the output from the envisaged 26 underwater plants. These stations were to cover the total course of the Lech from Fuessen/Allgaeu to Augsburg, producing a total capacity of 223 MW. Only eight were constructed, and these since 1939, with a total capacity of 52 MW and an annual output of 250 M.kWh. The Lower Lech stations are older and serve local consumers rather than feeding into the combined grid. They have an installed capacity of 25 MW and generate an annual average of 150 M.kWh.

Through the effort of Oscar von Miller, one of the pioneer agitators for the development of hydro power, Bavaria was the first region in Europe to plan systematically the utilization of the water of an entire river from its source to its mouth. This was the Isar River development. The Walchensee furnishes a natural reservoir at the source of the river. On this mountain lake the Walchensee power station, the first large hydro station in Germany, was completed in 1922. By to-day's standards the station is somewhat old-fashioned, but its output remains one of the most reliable sources of electrical power in Bavaria. It has an installed capacity in three-phase machines of 70.5 MW and in single-phase machines, for the supply of power for Bavaria's electrified railroads, of 53 MW. Its present average annual generation is 180 M.kWh and the lake has a storage capacity of 78 M.m³. Sometime before the end of the war, Bavaria commenced a project which would divert a portion of the waters of the Rissbach, heading in the Austrian Alps, into the Walchensee. The diversion, by providing increased water, would make it possible to generate an additional 90 M.kWh a year in the Walchensee hydro station without any increase in machine capacity. The war naturally stopped construction. Recently, however, Austrian, Bavarian, and Western Military Government authorities have reached an agreement for proceeding with the project; work has already been resumed and will probably be completed by the end of this year. The agreement to resume construction is a good example of successful co-operation in difficult international, legal and technical matters; it is the sort of necessary international co-operation that is essential if Europe's total hydro potentialities are to be realized.

The development plan for the Isar divides that river into three sections: the upper Isar from the Austrian border to Munich, the middle Isar from Munich to Landshut and the lower Isar from Landshut to its mouth. The middle Isar is completely developed and generates 400 M.kWh annually at stations with a total capacity of 82.5 MW. Financial arrangements are now being made through German sources to proceed with the development of the lower Isar with the installation of 143 MW in seven stations for an annual generation of 600 M.kWh. Most of the stations on the Upper Isar were constructed by chemical works near Munich to provide their own electricity. Further extensions will be made only after the development of the lower Isar is finished.

The most promising river for further hydro installations in Bavaria is the Inn. Being a border river between Austria and Germany for several miles of

Under-water Hydro-Power Station on River Lech



Another view of the Lech Station

its course, its future development is of mutual interest to both countries. Only in the lower course of the river has there been much exploitation. Three large stations have been constructed: Toeging near Muehldorf, to supply a large Bavarian aluminium plant, Ering and Obernberg (sometimes called Egglfing), built during the war to supply a large aluminium plant at Ranshofen in Austria. Since the two stations Ering and Obernberg are border power stations, by mutual agreement, both Germany and Austria share equally in their output. The Ering and Obernberg stations together have an installed capacity of 100 MW and an output of 660 M.kWh per year. Negotiations, sponsored by the Combined Military Governments, are at present in hand to form a joint Austrian-German company to take over and operate the present Inn River border stations and to develop further hydro plant along that portion of the Inn which forms a part of the international boundary. This is an international power development in the strictest sense.

Further development of the Danube is being undertaken by the Rhein-Main Donau AG, but as yet it is in the planning phase only. The Rhein-Main Donau AG is primarily a transport company. Their plans chiefly concern a connecting waterway between the Rhine and Danube rivers; the generation of electricity is only incidental.

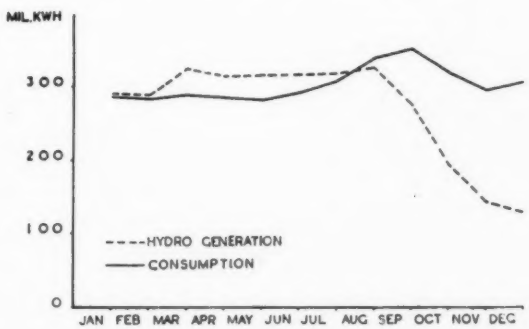
It should be noted that the Bavarian power supply, dependent as it is on run-of-river hydro generation, is unstable and varies greatly with the weather and the flow of the rivers. This is shown by the curve in Fig. 2. Before the war the difference in hydro generation was compensated with thermal power from what is now the Soviet Zone of Occupation. Since that power is no longer available all possible aid, during periods of low water, must come from the already heavily taxed thermal resources of the north. Limited transmission capacities have hindered Bavaria from sharing her hydro power with the north during periods of maximum hydro generation. New hydro stations and extensions to existing ones, and a new 220 kV transmission line in construction from Nurnberg to Frankfur/Maine, are designed to correct this situation.

Now let us consider the Upper Rhine and Black Forest group of hydro stations in South Baden. Between, Basel, Switzerland, and the small German village of Waldshut, Rhine water power has been thoroughly exploited. Difficulties due to this waterway forming international boundaries were settled by mutual agreement in the beginning of the century. The following table shows the existing important stations, their capacities and output.

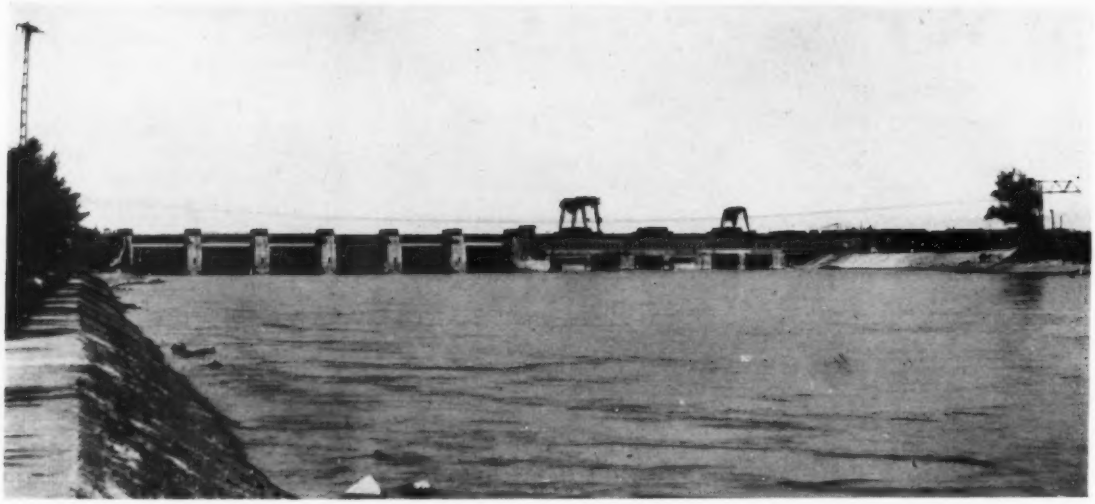
UPPER RHINE POWER STATIONS

	Augst-Wyhlen	Rhein-felden	Ryburg-Schwörst	Laufen-burg	Albbruck-Dogern	Reckingen	Eglisau
Water capacity m^3/s ...	800	614	1200	800	1060	500	405
Power capacity in MW	43.0	22.6	106.0	65.0	73.6	34.8	33.0
Average generation millions of kWh/ year ...	310.0	170	760	430	530	212	229
German share % ...	50	50	50	50	78	50	7
Number of machines ...	20	20	4	10	3	2	7

BAVARIA'S POWER CONSUMPTION AND HYDRO POWER GENERATION IN 1948 *(Fig 2).*



The Rhine east of the confluence of the Swiss river Aar to Lake Constance has not yet been developed, but plans for its use have been completed. Not only Switzerland and Germany are interested in this project, but also Austria as she would welcome the navigability of the Rhine up to the lake of Constance. Austria's interest in the project has increased since



Ering Power Station on the River Inn

last year's Danube conference deprived her of access to any waterway not controlled by the Soviet sphere of influence. Recent negotiations in Switzerland may result in an international monetary basis for the construction of both power stations and waterways.

The war and immediate post-war conditions halted construction at the Waldshut station, the last step of one of the largest hydro power projects in Western Germany, the Schluchseewerke. The Schluchsee itself, situated in the southern extreme of the Black Forest, is a natural storage reservoir. Its dam, constructed in 1929—30, increased the water volume to 108 M.m^3. Water flows through a seven km tunnel from the reservoir to a point 250 m above Häusern pumping power station where four generators of 23 MW each generate a yearly average of 135 M.kWh. From Hausern the water flows on to the Schwarza basin, and continues at a head of 248 m to the Witznau power station and generates a yearly average of 350 M.kWh through an installed capacity of 180 MW. Witznau as well as Häusern has pumping units, Witznau 104 MW and Häusern 80 MW. The water finally runs through Waldshut and there enters the Rhine. The pumps are operated at off-peak hours with power furnished through the transmission grid from the northern thermal stations, thus converting cheap night and off-peak power to peak load power according to the varying conditions of availability and demand at an efficiency of about 60 *per cent*. Häusern is Germany's first large vertical shaft pumping station and it has operated satisfactorily for 15 years.

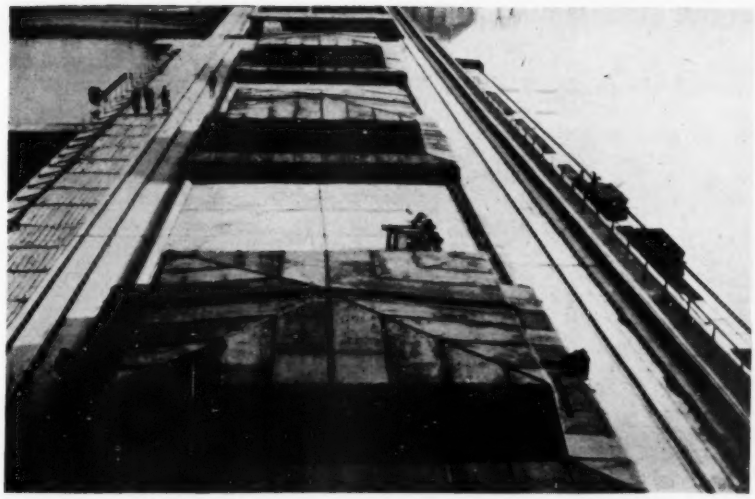
Far removed from the natural hydro sources of southern Germany, and situated in the industrial Ruhr at Herdecke, is Koepchenwerk, the immediate predecessor of the Häusern power plant of the Schluchsee aggregate. It is operated from an entirely artificial pump storage basin and was constructed in 1926—30 strictly as a peak power plant. The contents of the storage basin are completely emptied when generating at the full capacity of 160 MW in about four hours. In spite of the very small load factor of such a plant, its owners (Rheinisch Westfaelische Elektrizitaetswerke) state that its construction expense of some 50 M.RM has been justified. It has given them an appreciable amount of power, if only for a short duration, for the Ruhr industries; and it can be made available in a matter of a few minutes.

In Hesse the similar pump storage station of Waldeck uses the storage volume of Edersee. Water is pumped from the Edersee into an artificial reservoir above the station with the generators acting as motors to operate the pumps and drawing their power from the combined grid at off peak periods. When peak power is needed, the cycle is reversed; the pumps are disengaged through automatic devices, the motors become generators and power flows from the station back to the grid. Waldeck has an installed capacity of 140 MW and generates a yearly average of 100 M.kWh at a cost of 70 M.kWh for pumping the water back into the high-level reservoir. Below the Edersee dam are two small and conventional hydro stations, Hemfurth I and II.

All rivers and larger streams in Western Germany have been surveyed and thoroughly examined as to their hydro power potentialities. The extent of construction was in the past and is to-day dependent upon a number of sometimes local, sometimes international financial and technical conditions. This is particularly true locally when hydro power has to compete in the same area with power from other sources. Questions of stream-navigability are also involved. Naturally a power development becomes more economical if a portion of its total cost can be charged to water transport. An example of this is the proposed further development of the Rhine-Main-Donau AG, already mentioned.

The Neckar river is a small and picturesque stream, but its water power possibilities were successfully exploited long before the last war. A number of small stations of standard Kaplan turbine type were installed in connexion with a series of dams and locks and canals, which made the river navigable for smaller barges through two-thirds of its length. Thus this development gave to the area 25 MW of additional capacity with an annual output of 120 M.kWh of greatly needed power.

In northern Germany hydro power plays a minor rôle. The few stations are small and of only local importance. There are no future appreciable possibilities in this area.



Ering Power Station — an unusual view

As long as 15 years ago most of the projects described were either under construction or partly in operation. During the period of the Third Reich, all planned schemes were examined and re-examined and, in some instances, cancelled or altered in the course of rearmament. The two large Inn River stations Ering and Obernberg, the eight Lech River steps, Witznau in the Black Forest and Albbruck-Dogern as well as several small scattered stations were completed. There are two principal reasons for the comparative small progress during this period. The growing power demand of a rapidly expanding industry could only be met by the shorter construction time of thermal stations. Also, emphasis on hydro power development was given to the more favourable possibilities in Austria. As early as 1926 two large German companies, the Energie Versorgung Schwaben and the Rheinisch Westfaelische Elektrizitaetswerke, by agreement with the Austrian state of Vorarlberg, began the construction of a large hydro power project in Western Austria, the Vorarlberger Illwerke. As agreements made between the Austrian government and the two German companies called for at least 90 *per cent.* of the generation by this scheme to be delivered to Germany, it detracted interest from other developments within Germany. This was true also of the development of other streams such as the Enz, the Mur, the Upper Inn, the Upper Lech, all in Austria. The present and final ownership of the Vorarlberger Illwerke project will not be decided until the Allied Governments have made a decision on all German assets in foreign countries. Meantime 95 *per cent.* of its average output of 600 M.kWh a year is again being delivered to Germany as an import under a contract negotiated between the Combined U.S./U.K. Military Goverments and the Austrian Goverment in 1947.

Germany's hydro power projects suffered surprisingly little damage during the war. The successful bombing by the R.A.F. in 1943 of the Moehnesee dam in the Ruhr area and the Edersee dam near Kassel had a greater effect on the water supplies of the two areas than on electricity. At Moehnesee the entire central section of the dam was broken, a 10 MW hydro station was totally washed away, and the impounded water surged down the Ruhr valley, overflowing the lower basin of the Koepchenwerk and completely inundating all four machines. Seven months were required to remove mud and thoroughly dry the generators. Plans have been completed for the rebuilding of the Moehnesee power station, but its construction has not yet been started. At the Edersee, the damage to the dam was not so great, but great enough to flood both of the Hemfurth stations and the Waldeck pump storage station. No permanent damage was done to the stations proper, and repairs were successfully completed within six months. Two of Waldeck's four transformers became defective late in 1945 as a direct result of their being flooded after the bombing of the dam. During their repair in the power plant's own workshop fumes from the transformer oil were accidentally ignited and both transformers were destroyed. The station's workable capacity is still limited by 25 *per cent.* because of the inability to replace one of the two destroyed transformers.

No war damage was inflicted on hydro stations elsewhere. One of Arno Fischer's chief points in selling the idea of underwater stations to the government ministers was his claim that the stations could not be seen from the air and were invulnerable to air bombardment. The Luftwaffe's own pilots claimed that the tailwaters of these stations were plainly visible from high altitudes and that they could have easily been destroyed.

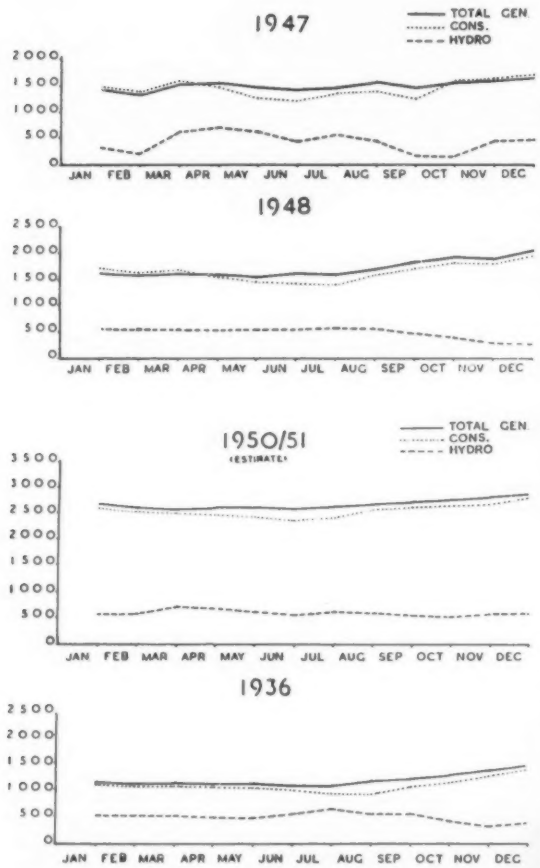
Immediately after the war resumption of hydro development was impossible because of general material shortages. For two years following cessation of hostilities, available materials were insufficient for even proper maintenance for existing thermal and hydro stations and the transmission grid. As steel and other essential materials became more plentiful, the German authorities, together with the Military Goverments, drew up plans for a power plant rehabilitation and extension programme. This plan includes the 82 MW of additional hydro capacity already described. The plan suffered an appreciable setback with the German currency reform of June, 1948, when it became impossible to obtain long term credits or any credits at tolerable interest rates. Because of the very appreciable shortage of electricity and generating capacity in the bizonal area of Germany, and the fact that this shortage has already become the principal limiting factor to further industrial revival, the Military Governors have recently taken action, in conjunction with the German authorities, to see that credits are provided to complete at least 20 of the power plant extension schemes as soon as possible. These 20 projects, all having been started and some as much as 80 *per cent.* completed, were selected because they will yield the greatest capacity in the shortest time with the least amount of material. They total 1,236 additional MW, of which 82 MW are hydro projects to yield an additional 400 M.kWh a

year. This figure includes the 90 M.kWh additional yield from the Riesbach diversion project.

Now all of the old plans are coming up for review and it is highly probable that, with international co-operation, considerable progress will soon be achieved. Undoubtedly, the border-stream stations will attract international financial interest. The Braunau project on the lower Inn River and the Jochenstein project on the Salzach River are included in an international complementary programme of the Office for European Economic Co-operation. A widely studied and once abandoned scheme which would affect Germany's power supply, the Our River scheme near the Upper Mosel in Luxembourg, is again being reviewed in an international power plant programme. If completed, Germany will supply the night power for pumping and share in day peak power output.

Switzerland has indicated an interest in the further development of the Upper Rhine after the solution of financial problems arising from the complicated post-war status of border river power stations. The further development of Western Germany's hydro power is closely linked with such an international development.

CONSUMPTION HYDRO AND TOTAL GENERATION IN WESTERN GERMANY



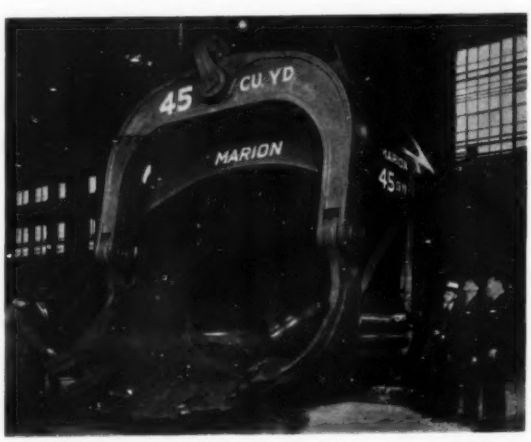
The graphs (Fig. 3) show the total electricity consumption, the total generation and the hydro generation in the U.K., the U.S. and French Occupation Zones of Germany in 1947 and 1948 compared to that of 1936, as well as an estimate for 1950/51.

Present available hydro power in southern Germany and Austria is used to share peak loads in Germany within the combined transmission grid operating with the Ruhr, Cologne and Aachen districts, coal and lignite steam stations.

A summary of the German situation would be incomplete indeed if plans for connecting other European hydro power sources were not mentioned. Plans visualized as early as 1926 are becoming increasingly important and are gaining support within the framework of O.E.E.C.

It is becoming more apparent daily that the European States must work together in assisting the further development of all power sources and an adequate transmission system to make power readily available to the mutual and total benefit. Norway and Sweden both offer great opportunities for a considerable contribution to Europe's hydro power. Plans are being created now for a further exploitation of lignite stations and the construction of several thermal stations in the Ruhr to use unsaleable and unused low grade hard coal. Such stations, of considerable international importance, will provide a large quantity of cheap thermal power, and it is not at all impossible or improbable to increase hydro power's contribution to valuable peak power in a broader European scheme. This can be done with pumping stations on a daily or weekly basis with high mountain reservoirs in the north and south of Europe contributing on a seasonal basis. Switzerland, France and Belgium are already connected to the Central European grid system in Western Germany. If the proposed 400 kV transmission lines materialize this grid system will be greatly strengthened, and hydro power will play a far more important rôle.

The World's Largest Shovel.—With the gigantic machinery involved, no conclusions can be drawn until the big dipper has thoroughly proved itself. This experiment is expected to take from 6 to 9 months. See page 134.



Model Tests

By Dr. MARIO MEDICI, Professor at the University of Padua, Italy. A study of the relationship between model tests and the results of full-scale water turbine experiments.

Une étude du rapport entre les résultats des essais sur maquette et le rendement des turbines hydrauliques grandeur nature. La similitude géometrique est rarement atteinte, écrit le Dr. Mario Medici; la relative rugosité des surfaces métalliques mouillées diffère inevitablement de maquette à turbine. Il en résulte que, de l'une à l'autre, les pertes par frottement sur les surfaces d'ailettes et de tuyère, et, partant, le rendement, varient nécessairement. L'auteur donne une formule permettant de prédire la capacité nominale des turbines hydrauliques à partir des essais sur maquette.

Un estudio de la relación que existe entre las pruebas de modelos y los resultados de experimentos con turbinas hidráulicas de escala completa. Difícilmente se logra una semejanza geométrica, dice el Dr. Mario Medici; hay una diferencia inevitable en la aspereza relativa de las superficies metálicas humedecidas del modelo y de las turbinas de tamaño completo. Como consecuencia, las pérdidas de fricción sobre las superficies de los tubos y de las paletas de turbina no concuerdan con las del modelo a escala, causándose diferencias en la eficiencia de la turbina. El autor explica una fórmula para predecir la capacidad clasificada de las turbinas hidráulicas a base de pruebas con modelos.

THE phenomena of hydraulic resistance and of hydraulic similarity was first studied by Leonardo da Vinci about the year 1500, but the earliest definition of the principles of similarity was published by Sir Isaac Newton in his *Principia* (1687). Further intensive work on the subject was not undertaken until 200 years later.

The law of hydraulic similarity was stated by Stokes (1850) as — "Two systems, model and full-size, in which only the forces of viscosity are considered as being present and acting, and where the forces of gravity do not appreciably affect the resistance, are dynamically similar if corresponding velocities are directly proportional to the kinematic viscosities, and inversely proportional to the linear dimensions."

About 70 years ago Francis made some experiments with a small model of an inward-flow turbine at Lowell, Massachusetts, U.S.A., to determine its efficiency; but there does not appear to have been any broad recognition of the law of similarity. It is now 50 years since Froude made his researches on the forces required at various velocities to tow different models of ships through long tanks; and a dimensionless term derived from the expression $\frac{r_i \cdot g}{c^2}$ (where the symbol r_i = hydraulic radius, g = acceleration due to gravity, and c = average velocity of flow) has been called *Froude's number*, after the great experimenter.

The first attempt to solve the problem of determining the scale-effect with some references to water turbines and pumps was carried out by Professor Osborne Reynolds about 1883, and by the German Professors Hubert Engels and Gustav Zeuner, about 1890. The law of hydraulic similarity is called the *Reynolds Law* for Corresponding Velocities, after Osborne Reynolds, since he was the first to make use of the Stokes principles and to determine values for the expression:

$$\frac{c.\,l}{V} = \frac{c_M.\,l_M}{V_M}$$

(where the index M indicates "model," and the symbols l = length, and V = kinematic viscosity). These experiments were concerned with the flow of water in pipes. It is now customary to express with the letter R_d the above expression, where R_d is called the *Reynolds Number*, and is a dimensionless numerical quantity which is, therefore, the same whether metric or English units are used. If liquids of the same viscosity and the same temperature are employed in both the model and prototype systems then $V = V_M$ and the condition for hydrodynamic similarity will be $c.\,l = c_M.\,l_M$.

A later research worker in this field, who sought to establish the influences of the scale-effect on rate of discharge and on the efficiency of water turbines, was the German scientist, Professor Rudolf Camerer. About 1906 Camerer introduced the very important concept of "specific speed" which may be considered as the combination, in a single expression, of the fundamental laws of hydrodynamic similarity applied to water turbines and pumps. If we consider a system of water turbines, all geometrically similar[1] but built to a different scale; and if we suppose that these turbines run at different velocities, then there is one particular speed of rotation at which the efficiency of all the turbines reaches its highest value; and this speed is the speed for which they have to be designed.

Now it is important to consider that the geometrical similarity is seldom completely realised. There is an inevitable difference in the relative roughness of the wetted surfaces of model and full-size turbines. Therefore, the friction losses on the surfaces of turbine blades and pipes are bound to vary with the scale of the model, and thus cause a difference in the turbine efficiency and also in the turbine discharge[2].

Fundamental Similarity Considerations

Similarity considerations of water turbines deal with the attempt to describe the performance of a given

turbine by comparison with the experimentally-known performance of another similar turbine called the model, which is not only geometrically similar to the larger machine, but shows also the similarity of flow. As previously indicated dynamic similarity is exactly satisfied if the " viscosity forces " are proportional to the inertia forces; that is if the *Reynolds Number* does not change. This condition is of limited importance in the water turbine field, because in ordinary laboratory models the fluid passages through the guiding surfaces of the model turbine are sufficiently large, the water velocities are high, and the blade surfaces are of sufficient roughness to correspond with similar quantities in the larger machine and turbulent flow exists. The *Reynolds Number* is ordinarily of a value far removed from the critical value, and the " viscosity forces " are then of little importance in relation to the inertia forces. These considerations, however, do not apply to turbomachinery of very small dimensions and velocities, or for fluids of high viscosities, or appreciable compressibility, or (in the field of water turbines) for cases involving cavitation[3].

For these conditions it is necessary to observe additional similarity relations, and the *Reynolds Law* then constitutes a severe restriction on the application of the simplified similarity relations, often called " fundamental " in contrast to those concerning cavitation. The turbine velocity fluctuations are not taken into account in these notes when considering the fundamental similarity relations.

The similarity of flow conditions requires careful definition. The flow conditions in two geometrically similar turbines shall be considered similar if all fluid velocities are changed according to the same ratio when going from one system to corresponding points in another. All fluid velocities shall have the same direction at similar points, which means that not only the total velocities, but also their various directional components shall be changed in relation to each other. All velocity vector diagrams shall be geometrically similar at corresponding points in the turbine model and in the full-size machine.

Relative motion invariably exists in the turbines between the runner and the other guiding surfaces of the machine; this affects the geometry of the flow conditions and thereby introduce an element into the similarity considerations that makes it convenient to start with the simplest possible assumptions, which are:—

1. That the inertia forces are the only forces acting on the water, and
2. That the water is considered as incompressible.

The similarity of the velocity diagrams implies a constant ratio between the water velocities and the peripheral speeds of the runner at all geometrically similar blading points of the turbines under comparison. For turbines and pumps, where the rotational speed n, the capacity Q and the head H are the most significant operating characteristics, the ratio above assumes the form:—

$$\frac{Q}{n \cdot D^3}$$

Where D indicates the runner's diameter, since the water velocities c are proportional to $\frac{Q}{D^2}$ and the peripheral velocities are proportional to nD. The dynamic relations between the head and the velocities in the turbine have the following form:—

$$\frac{H \cdot D^4}{Q^2} = \text{const. and } \frac{H}{n^2 \cdot D^2} = \text{const.}$$

It is known that one geometric design of water turbine can be used to cover a large variety of operating conditions merely by changing the speed of rotation or the size of the turbine, or both. One form of design is not sufficient to cover all possible operating conditions. Camerer's parameter of a specific speed, forming a new symbol with the three most important operating characteristics of a water turbine is indicated by

$$n_{sQ} = \frac{n \cdot \sqrt{Q}}{H^{\frac{3}{4}}} = n \cdot Q^{0.5} \cdot H^{-0.75}$$

and is a new relation for the operating conditions, being independent of the size of the machine, and not containing its representative dimension D.

A fixed value of the specific speed describes all operating conditions (n, Q, H) that can be satisfied by similar flow conditions in geometrically similar water turbines. A turbine of given geometric design satisfies not only one specific speed, but a range of others. It is thus impossible to correlate definitely the specific speed with the hydraulic design of water turbine. Such correlation can be established by considering only those operating conditions at which the turbine has its best efficiency. The specific speed of a water turbine is by convention designated as " the specific speed at best efficiency "; and thus becomes an index of the design by describing its operating characteristics under best efficiency conditions.

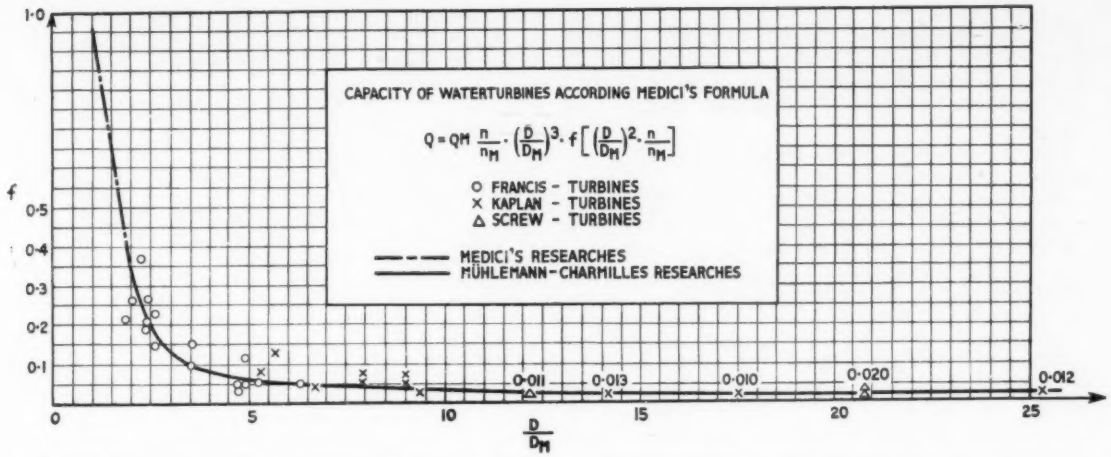
The foregoing similarity relations can be derived also by the purely abstract methods of dimensional analysis. Since these relations are based on the simplified assumptions it is necessary to check their validity experimentally.

Care must be taken to check the complete geometrical similarity including the surface roughness, the running clearances, and so on, and the similarity of flow conditions.

The performance characteristics of a water turbine as evaluated from the test results of its " model " often require a correction due to the scale-effect (assuming that the geometric shape of the water passages and the leakage clearances, and average surface roughness are as nearly as possible similar to those of the full-size turbine). The scale-effect is specially important in relation to the capacity and efficiency of the turbine, and its operation rises from the fact that the compared machines can seldom be strictly similar if their absolute dimensions are very different.

Scale-Effect and its Relation to Capacity

In order to ascertain the value of the scale-effect upon the capacity of water turbines, and to derive a " model law " for predicting the capacity of a new machine from test results on a model of similar dimensions, research work was carried out for many years by the author on several turbines, both of Francis and Kaplan types, as well as on different models of them in the Machinery Institute of the University of Padua. Several scales were adopted, and care was taken that the models should exactly reproduce the original even to the roughness of the wetted surfaces. Inquiries were also made into the behaviour of various models at different speeds, and in the case of the Kaplan turbines the behaviour was investigated in relation to the influence of the chief



angles of inclination of the runner blades. Under properly prepared conditions of faithful geometric reproduction, accurate similarity of flow conditions, and suitable roughness of the blading and turbine surfaces, it was found that for the rated capacity the apparent scale-effect depended on the ratio of the *Reynolds* numbers of the compared turbines, namely:

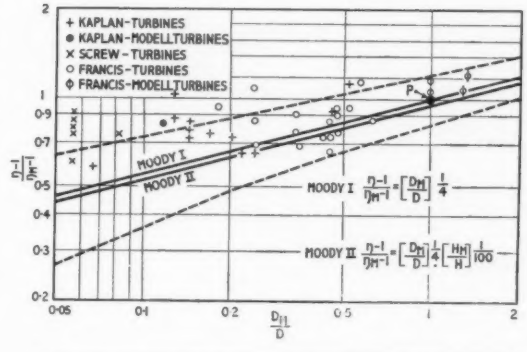
$$Q = Q_M \frac{n}{n_M} \left[\frac{D}{D_M}\right]^3 \cdot \quad f\left[\left(\frac{D}{D_M}\right)^2 \cdot \quad \frac{n}{n_M}\right]$$

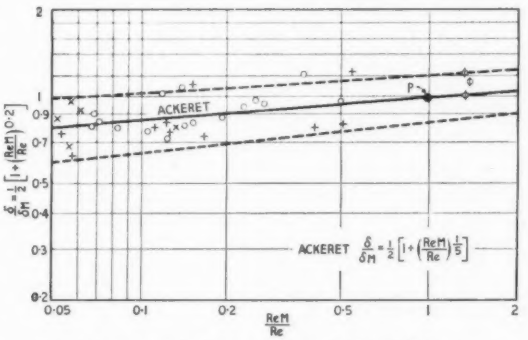
A curve was plotted of the values of the f-coefficient of this equation. The effects of turbulent and viscous friction have been found to correspond to the *Reynolds Law* of similarity, and to the *Reynolds* number-effect, which cannot be theoretically predicted. The scale-effect can be accurately determined only by practical tests mainly because of conditions connected with unstable flow. The relationship applies also to water pumps, the only variant being the numerical value of the f-coefficient.

Because of the limited facilities in the author's laboratory, it has not been possible in these researches to exceed the scale ratio of 1 : 2.5. Therefore, in Fig. 1 the curve indicated by a dotted line shows the f-coefficient values derived from the author's researches, while the full-line curve shows the f-coefficient values determined by Dr. Mühlemann's researches. Dr. Mühlemann has courteously placed at the author's disposal a very large collection of tests on 40 water turbines built by the *Ateliers des Charmilles*, Geneva, made during 20 years from 1926 to 1946. Seven of these were models. It is of interest to note that these turbines cover the entire field of specific speeds (n_{sQ} from 26 to 240) for Francis and Kaplan turbines, while they operate with outputs ranging from 250 kW to 40,000 kW. The curves show a clear relationship one with the other, and the author claims that the diagram confirms the reliability of his formulæ for predicting the rated capacity of water turbines from model tests.

One of the accepted " model laws " for predicting the efficiency of a new water turbine from test results on a model of appreciably different dimensions is given by L. F. Moody. He has produced two formulæ known as the Moody I[4] and the Moody II[5]; recently he has re-stated the derivations of these equations in the " Handbook of Applied Hydraulics."[6]

They are based on the assumption of purely turbulent friction losses, and approximately constant





From top down—Figs. 1, 2 and 3

absolute surface roughness of the fluid passages in the turbine. No specific assumption is introduced concerning the change in the relative size of the running clearances, nor are bearing and mechanical losses taken into account. The exponential is given by Moody as approximately 1 : 5, but it is important to note that this relation may become appreciably smaller if the " model " of reduced size has very smooth walls and close running clearances.

Professor Ackeret[7] has given a relation in this form

$$\eta_i = 1 - 0.5\ (1 - \eta_{iM}) \left\{1 + \left(\frac{R_{d\,M}}{R_d}\right)^{0.2}\right\}$$

where η_i indicates the hydraulic efficiency.

The derivation of Ackeret's formula is based on the fact that the hydraulic losses in a water turbine have a minimum value when half the losses are kinetic

losses, and the other half are friction losses. Only the losses of head due to friction have to be considered in the evaluation of the scale-effect. The influence of the *Reynolds Number* is assumed proportional to an exponent of 0.2.

Dr. Mühlemann has elaborated the results of the tests in order to establish whether Professor Ackeret's formula gives a better accuracy for the efficiency step-up than did the formulæ Nos. I and II of Moody. The results of his investigations are reproduced in Figs. 2 and 3, which indicate that Professor Ackeret's step-up formula gives a fairer accuracy for predicting the hydraulic efficiency of a new water turbine. The point marked 'P' on both diagrams indicates the value of a "reference turbine," namely the model of a Francis turbine developing 34,600 kW, when the specific speed is $n_{sQ} = 35$. On this model and on the full-size turbine very accurate and detailed performance tests have been made.

1 In order that two systems, of model and full-size water turbines, shall fulfil the requirement that they be geometrically similar, it is necessary that the ratios of all corresponding linear dimensions are the same.

2 Two systems, of model and full-size water turbines, fulfil the requirement that they shall be dynamically similar if they are geometrically similar, and if the corresponding losses of head due to friction and to other hydraulic losses along the turbine are in the same ratio as the corresponding dimensions.

3 The phenomenon of cavitation is a local vaporisation of water caused by local pressure reductions due to dynamic action. It is characterised by the formation of vapour pockets in the interior of a rapidly moving stream in the runner blading of a water turbine or pump.

4 L. F. Moody—The Propeller Type Turbine. Proceedings of the American Society of Civil Engineers (1925).

5 L. F. Moody—Efficiency and Power Step-up. Proceedings of the American Society of Civil Engineers (1939).

6 Davis-Calvin—"Handbook of Applied Hydraulics." McGraw Hill Co. Inc. (1942).

7 E. Mühlemann—"Zur Aufwertung des Wirkunggrades von Ueberdruck-Wasserturbinen." Schw. Bauzeitung (1948), No. 24.

Severn Barrage Scheme

IT was disclosed in the House of Commons recently that a new tidal model for the Severn Barrage scheme was being constructed. Mr. Peter Freeman, Labour Member for Watford, asked the Lord President of the Council whether the model made by the department of engineering of Manchester University in 1926—30 was being used in connexion with recent researches.

Mr. Herbert Morrison replied that this model was dismantled several years ago when the researches for which it was constructed were completed.

Commenting that the information from this model would be of value, Mr. Freeman asked whether, in view of the fact that it was two years since the new committee was appointed, Mr. Morrison could say why there had been so much delay and when they would get a report on the scheme.

The Lord President said they would get the report as soon as the work was completed. He understood that all the information which resulted from the Manchester University model was still available and that they had been constructing a better and larger type of model which would be more effective for the purposes in hand.

British Industries Fair

Birmingham, May, 1949

IT is, of course, understandable that hydro-electric plant could not be shown except in model form at an engineering exhibition, however extensive; and therefore manufacturers of such plant in their exhibits at the British Industries Fair, 1949, naturally concentrated on other products capable of physical demonstration in full-size form.

Photographic displays, however, showed an increasing number of British firms whose products concerned either directly—or at one stage removed—the field of water power. These displays formed an interesting study for the many visitors from abroad, who perhaps reinforced their impressions of the Fair by subsequent visits to the manufacturers' works.

Whatever may be the outcome of the battle between a.c. and high-tension d.c. transmission systems, for linking remote hydro-electric installations with the centres of load, the exhibits at the Birmingham section of the B.I.F. showed beyond doubt that British manufacturers are able to produce switchgear for 3-phase a.c. systems commensurate with the trends towards higher voltages and larger power flows per circuit. For instance, the B.T.H. company showed an oil-filled circuit breaker for 275 kV, with a short circuit breaking capacity of 2,500 to 3,500 MVA. A single unit of the 3-phase breaker was transported to the Fair, and was perhaps the largest piece of apparatus ever exhibited at an engineering exhibition, standing as it did 23 ft. high and weighing over ten tons. Messrs. A. Reyrolle & Company also had on view a 132 kV minimum oil circuit breaker of a new design, in which pneumatic operation on the unit principle was employed. The English Electric Company showed models illustrating the principles of their air-blast circuit breakers which are suitable for the highest powers and voltages.

Among the very large number of exhibits in the mechanical engineering section, there were models and portions of full-scale equipment which showed that for construction work on hydro-electric sites there were improvements in every type of auxiliary plant likely to be needed. The trend towards complete mechanisation of such operations as excavation, road making, concrete mixing and the like, was exhibited by examples of such equipment in the outdoor area adjoining the engineering section. Many exhibitors stated that delivery times, at any rate of the small items of constructional plant needed on hydro-electric sites, were gradually being reduced.

Lord Forrester, M.A., and **Mr. Erroll, M.P.,** discussed the possibility of Tasmania supplying Victoria (Australia) with electricity by submarine cable under the 200 mile wide Bass Strait in a recent broadcast from London.

Following this broadcast, which was arranged by the Australian Broadcasting Commission, Mr. Johnson, Federal Minister of the Interior, said in Launceston, Tasmania, that in other parts of the world hydro-electric power had been transmitted under the sea over greater distances than the width of Bass Strait. After inspecting the Butler Gorse hydro-electric scheme, Mr. Johnson stated that not more than one quarter of Tasmania's hydro-electric power resources had so far been exploited.

Excavating at Wet Sites

By R. G. ATTWOOD. The basic principle of the Wellpoint system of dewatering is the lowering of the water table of the whole area around the site to be excavated. Methods of operation are explained.

Le principe fondamental du système Wellpoint d'assèchement est l'abaissement du niveau hydrostatique tout autour du site que l'on se propose de creuser. Les méthodes d'opération sont ici expliquées. Le système a été très perfectionné et les difficultés du creusement dans le sable flottant ou dans un sol très imbibé d'eau ont été éliminées dans une si large mesure que les travaux de fondation peuvent y être menés à bien économiquement.

El principio básico del sistema Wellpoint de drenaje consiste en rebajar la base de agua de la totalidad de la superficie del terreno a ser excavado. Se explican los métodos empleados. El sistema ha sido desarrollado hasta alcanzar un alto grado de eficiencia y las dificultades relacionadas con excavaciones en arena movediza y en terreno pantanoso han sido en muy gran parte eliminadas, con el resultado de que los trabajos de construcción de los cimientos pueden ser completados de manera satisfactoria y económica.

A SITE for a new hydro-electric station might be ideal from the point of view of general location and economical operation, but it can present great difficulties to the constructional engineer who has sometimes to carry out the excavation of deep foundations when the site is heavily water-logged.

Those engineers experienced in the construction of foundations in " running sand " are fully aware of the difficulties to be overcome; the heavy costs incurred and the danger of subsidence in a locality adjacent to other buildings is a serious matter often involving heavy risks and liabilities.

In the first place he must employ piling apparatus to drive the steel sheeting around the site, with heavy timbering for framing and strutting, which often is a handicap to construction. Unless the sheeting can be driven down to a clay strata or on to rock, the external pressure of the water outside the sheeting causes boiling at subgrade and the " running sand," which is inseparable from the water, cannot be prevented from oozing behind the sheeting possibly causing a movement of the sheeting and subsidence in the locality. The ground at subgrade will be wet and unstable for laying the concrete base, and unless the site is piled, the weight of the concrete base may sink after laying due to displacement of the wet sand round the excavation, as it must be remembered that it is not possible to " compress running sand, but it can be displaced."

It is generally accepted that the most difficult conditions encountered during the excavation of a site are due to " running sand " or " quicksand." This is a condition of material, the fine sand being so heavily impregnated with water that it actually becomes fluid and therefore unstable. Until recent years it has been usual to open up a site, allow the water to flow in and then attempt to extract it by sump pumping. This allows the fine particles of sand to flow with the water and open up the voids, causing the water to become more free flowing, and movement or settlement of the ground behind the sheeting to take place. When in "running sand" it is practically impossible to separate the water from the sand, which causes heavy wear and tear on the pumping machinery.

Engineers realised long ago that if only the water could be extracted without causing movement of sand, the soil would become stable and any difficulties of excavating would be overcome. Many methods were tried, but it was only after years of constant experiment that a perfect and economical system was evolved. This is now known as the Wellpoint Dewatering System, and has been used on contracts of major importance all over the world.

The basic principle of the Wellpoint system of dewatering is the lowering of the water table of the whole area around the site, thereby reducing the head of water, preventing the movement of any soil and enabling the work to be carried out to subgrade under dry conditions. Often it can be done entirely without timber or steel sheeting, or where vertical sides are essential with skeleton timbering only. Excavating in running sand without timber may sound an impossi-

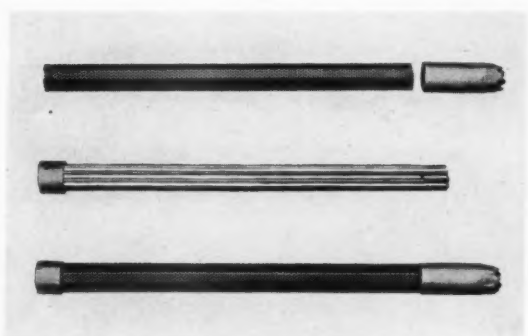


Fig. 1. The Wellpoint tool in parts, and assembled

Above: The initial stage (Fig. 2). Wellpoint attached to a riser pipe is about to be forced down. Below: A well-drained excavation ready for foundations

bility, but those who have experience of this system can verify the truth of it.

Most of the development work on Wellpoint dewatering in Great Britain has been carried out by Millars' Machinery Company, of Bishop's Stortford and Manchester. The Wellpoint itself consists of a fluted tube covered by a gauze screen. A shoe at the lower end contains a floating ball which acts as a valve to permit jetting water, and when the Wellpoint is installed to the correct depth, seals the end and causes the water under suction to pass through the gauze screen by way of the holes at the shoe end to the inside of the tube (Fig. 1). A riser pipe connects the Wellpoint to the header pipe through a swing connection with union and stop cock, so that any Wellpoint may be shut off, inserted or disconnected without breaking the vacuum or upsetting the balance of the system.

Jetting the Wellpoint into position is simply effected by forcing water under pressure from a high pressure pump or hydrant connected by hose to the top of the riser pipe and down through the Wellpoint, which is washed down into the ground to the required depth. When working in sand 40 to 60 lbs. per square inch is sufficient, but when passing through gravel or clay, a pressure up to 120 lbs. per square inch is necessary with a volume of 300 to 400 g.p.m. (Fig. 2). In running sand or very fine silt, the Wellpoint is " sanded in " to prevent any of the fine silt being drawn into the system. This is effected by placing coarse sand to replace the sand washed out while jetting. This sand sinks against the rising silt settling round the Wellpoint and acts as a filter, ensuring a perfectly clear

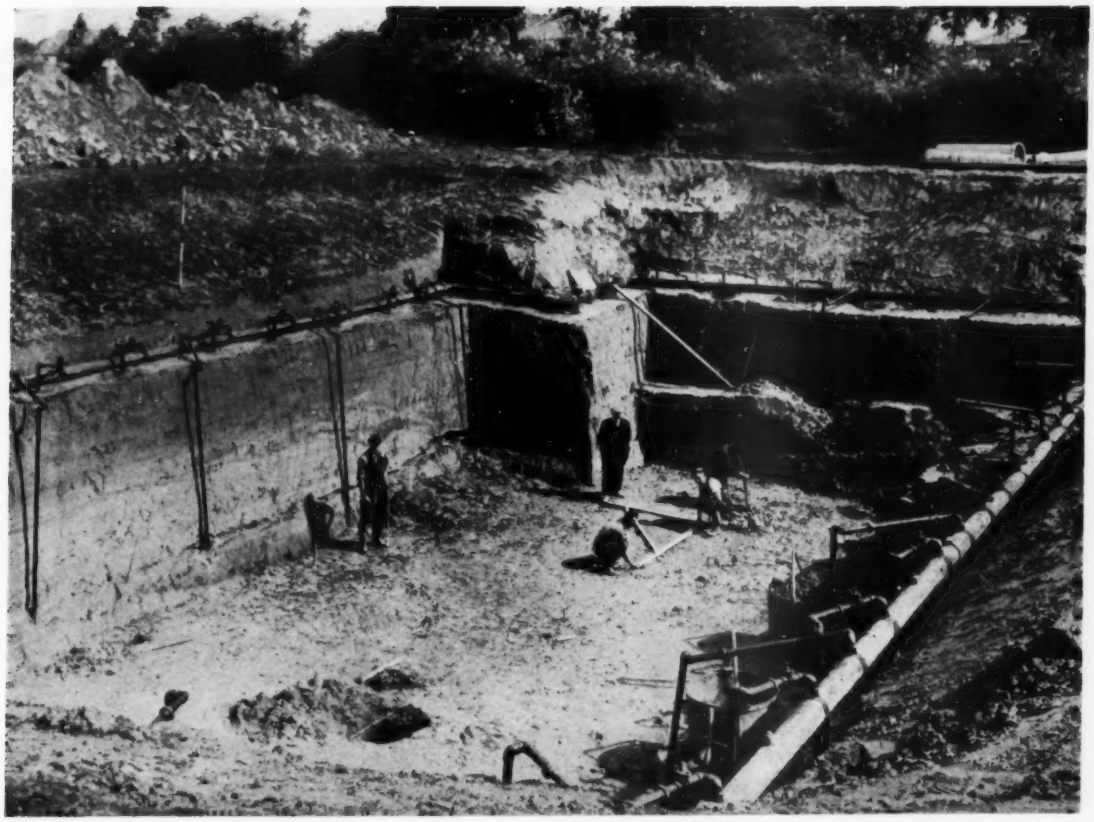


Fig. 3a: The "ring system," with header pipe encircling the area, and riser pipes with individual control valves

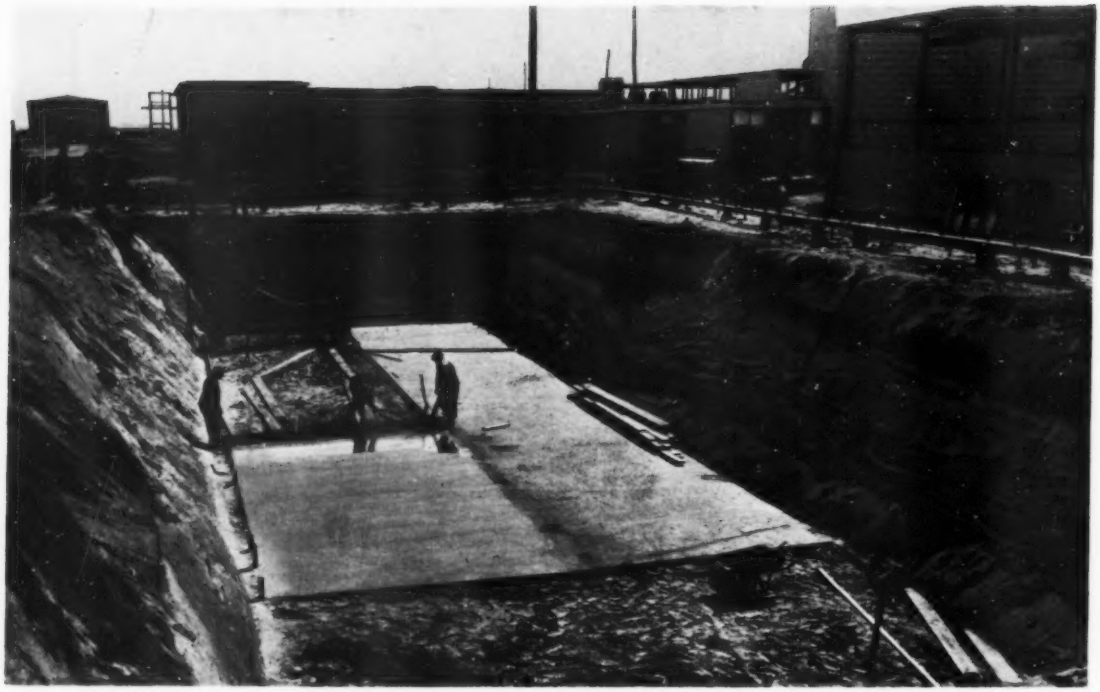
discharge of water through the pumps.

The Wellpoints when inserted are then connected through their riser pipes and swing connections to a main suction pipe or header pipe laid out at ground level or at permanent water level. The water is extracted from the ground by suction under vacuum, until the ground is firm and dry to a depth well below that of the proposed foundations or trench. All this is carried out before excavation commences.

Because of the long suction lines and the presence of air in the water, the pumps must be capable of dealing with large quantities of free air in addition to volumes of water up to 1,000 gallons a minute at 40-ft. head.

Where a site for an open excavation is to be dewatered, the "ring system" is used. The method adopted is to encircle the whole area, with the header pipes outside the building line. It is usual wherever possible to "batter" the sides of the excavation, as

Fig. 3b shows an earlier stage at the same site as Fig. 3a with the "ring system" operated by portable trailer pumps. The flooding is clearly seen in the photograph



Working in dry conditions. Notice the proximity of water in lower illustration

by this means the use of timber or steel sheeting can be eliminated in excavations 20 ft. deep or more, and the sides kept comparatively steep (Figs. 3a and 3b).

The Wellpoints are sunk and spaced according to the nature of the ground and the amount of water. If the depth of the excavation is to exceed 18 ft. below ground level, it is advisable to excavate to water level and "ring" the area at this depth, thereby reducing the suction lift and increasing the efficiency of the dewatering plant. For greater depths, two-stage work is used; the top area is dewatered and excavated first, and the area then "ringed" at the excavated level. By this means, excavations have been taken down to depths exceeding 50 ft. Pumping must be kept up day and night even when water has been lowered in the area, until constructional work has been completed up to normal water level.

For trenching, the "progressive system" is used, by which means the dewatering of the ground is kept ahead of the excavation, the Wellpoints being withdrawn where pipe laying is completed and inserted ahead of the work. The ground is thus dewatered prior to being opened up.

Dewatering may be so complete that precautions must be taken against the ground falling, specially where heavy excavating machinery is used, which might possibly cause vibration. In every case, however, the very minimum of supporting works is called for, with consequent economies. It will be obvious that the system cannot operate in clay. However, so long as the Wellpoints themselves are in sand, layers of clay can be penetrated by jetting, and the layers of running sand above and below the clay can be dewatered.

An important feature of the system is that the discharge water, which should be led well away from

Continued on page 132

Scottish Hydro-Electric Scheme

By Our Parliamentary Correspondent

ORDERS have been laid before Parliament confirming hydro-electric projects for the North of Scotland which will produce, when fully developed, 700 million additional units of electricity at an estimated cost of nearly £23 million. The constructional schemes outlined in the Orders contain one—the Glascarnoch-Luichart-Torr Achilty Project —which is the second largest undertaken by the North of Scotland Hydro-Electric Board.

The major scheme represents a development of that part of Ross and Cromarty already covered by the Loch Fannich programme and comprises a catchment area of 345 square miles. Eight dams and four generating stations with a total installed capacity of 60,000 kW will be needed. Two new reservoirs will be created, one in Strath Vaich by a 70 ft. dam and one in the Glascarnoch river valley by a 90 ft. dam. A tunnel five miles long will convey the water from this section of the project to the Glascarnoch generating station at the head of Loch Luichart. Loch Luichart will be raised 36 ft., the railway track to Kyle of Lochalsh will be diverted and the site of the present Loch Luichart railway station will be submerged.

The four generating stations to be constructed are the Glascarnoch station with an installed capacity of 24,000 kW, one near Grudie Bridge of 2,000 kW, one at Luichart of 24,000 kW, and another at Torr Achilty with a capacity of 10,000 kW, where a 45 ft. high dam will be built on the River Conon. A dam at the eastern end of Loch Fannich will raise the level of the loch by 20 ft. This will increase the storage capacity of the loch by about 47 per cent. and thus increase the output of the Fannich Power Station by 4 per cent., representing three million units of electricity annually.

This scheme is one of the major projects of the North of Scotland Hydro-Electric Board designed as a contribution towards meeting the shortage of electricity and, when fully developed, will produce an average of about 280 million units of electricity a year, at an estimated cost of £8,700,000.

Another scheme embodies extensions of the Loch Sloy Project and by making fuller use of the water power resources of the area will provide additional output from the generating station at Inveruglas, on the west side of Loch Lomond. Water will be drawn from new sources not tapped in the Loch Sloy scheme and five aqueducts will be constructed to collect this water and pass it into streams flowing into Loch Sloy. The Loch Sloy catchment area will be increased by about 4 square miles, making some 31½ square miles in all. The total average annual output of electricity from the generating station at Inveruglas will be raised from 100 to 115 million units, at an estimated cost of £285,000.

The Loch Dubh (Ullapool) Project, which is the subject of a further Order presented by the Secretary of State for Scotland, covers a catchment area of 5.1 square miles in the County of Ross and Cromarty. The main works consist of a low dam 18 ft. high and 220 ft. long across the Allt a'Mhuilinn below its junction with the stream issuing from Loch na Maoile, and another dam 35 ft. high and 175 ft. long built across Allt a'Mhuilinn near the outlet of Loch Dubh. This will convert three lochs into a single storage system to feed Loch Beinn' Deirg. The generating station will be built near the Ullapool-Lochinver road, to provide ultimately a capacity of 1,800 kW. The turbines will operate under a gross head of 511 ft. A steel pipeline 3,700 ft. long will connect Loch Beinn' Deirg with the generating station, and at a later stage a second pipeline will be laid. When complete the scheme will provide an average annual output of 4,550,000 units of electricity at an estimated cost for the whole scheme of £200,000.

The fourth scheme involves the construction of a concrete dam 1,250 ft. long and 70 ft. high across the Allt-na-Lairige, to form a reservoir some distance above its junction with the River Fyne. This dam will impound water from a catchment area of over five square miles and the water from the reservoir will be led by an aqueduct and pipe-lines to a generating station to be erected on the left bank of the River Fyne about a mile below the mouth of the Allt-na-Lairige. The station will have an installed capacity of 6,000 kW with an average annual output of 17½m units of electricity. This output will be transmitted to the Clachan generating station of the Shira project where it will be fed into the local distribution system. Any surplus will be transmitted to the Central Scotland Grid in the Glasgow area. The estimated cost of this scheme is £620,000.

MORISTON AND GARRY

Two more projects—the Moriston and the Garry —have been authorised by the Secretary of State for Scotland, who has advised granting the necessary authority for the North of Scotland Board to carry out the work. The schemes cover adjacent catchment areas totalling 309 square miles, and will develop the substantial water power resources of Glen Moriston and Glen Garry in the counties of Inverness and Ross and Cromarty, north-west of the Great Glen. The Moriston scheme will raise the level of Loch Foyne by a dam 1,542 feet long and 61 feet high, the water being conveyed by tunnel and pipeline to Loch Cluanie, the level of which also will be raised by a dam 2,015 feet long and 108 feet high. From this reservoir water will be conveyed to a generating station near Ceannacroc Bridge, with an installed capacity of 16,000 kilowatts. A subsidiary station (2,000 kW capacity) to utilise the waters of the upper catchment of the River Doc will be built north of the Ceannacroc station. The water discharged from the station on the Doc will be led into the tunnel and pipeline between Loch Cluanie and the Ceannacroc generating station, thus using the water twice over.

On the lower reaches of the River Moriston two dams will be constructed, and the water conveyed to

a power station with an installed capacity of 20,000 kW to be built at Invermoriston. A subsidiary generating station of 5,000 kW capacity will be built at Livishie to utilise water from streams now flowing into the River Moriston and Loch Ness, and the water from this station will discharge into the reservoir formed by the Moriston dam.

The Garry project will raise the level of Loch Quoich by a dam 806 feet long and 107 feet high at the eastern end of the loch. The generating station (installed capacity 20,000 kW) will utilise the water, which then will discharge into Loch Poulary on the River Garry. At the eastern end of Loch Garry a dam 1,026 feet long and 84 feet high will be constructed, and water conveyed to a power station (installed capacity 20,000 kW) at Invergarry.

These two schemes are designed to provide power for industrial development in the Inverness—Fort William areas, as well as to increase available electricity in other parts. Ultimately the Moriston project will produce an average of about 214 million units, and the Garry project 170 million units of electricity annually. Estimated cost of the Moriston project is £8 million, and of the Garry project £4,850,000.

Snowy River cont. from p. 104

the Far East, and while the connection between this decision and the hydro-electric schemes may not be apparent, it becomes significantly so when long-range weapons of the future are brought into the reckoning. So far most of the major industries of the continent have had to be located near the coast because of the need for power from coal resources. By contrast the new hydro-electric schemes for the Snowy River would enable them to be located in far less vulnerable centres than they are to-day.

That, however, is an essentially long-range aspect of the plans, and it may take 30 years or even more for them to reach fruition. Meanwhile, the "first step" recommendations of the engineers may well be made available in eight to ten years. There is no question, however, that as the Premier of Victoria, Mr. T. T. Hollway, underlined in his message to *WATER POWER* at the turn of the year: "Water Power will be the key to expanding industry." Kiewa and the Snowy River schemes, as they are envisaged, promise the first turning of the key.

Excavating at Wet Sites cont. from p. 130

the site to a local stream or drain, is at all times crystal clear and causes no pollution. The advantages of Wellpoint dewatering are summarized thus:

When working in "running sand" conditions of excavation are the same as for digging in dry ground.

Where a mechanical digger is used, it is possible to dig to the full depth of a trench at one cut, instead of operating to water level only, leaving the rest to be excavated by hand.

In pipe laying, a perfectly true pipe line is assured, as no sinking takes place.

Subsidence and consequent damage to buildings, roads, etc., are entirely avoided.

Working under dry conditions will speed up the work and greatly reduce the operating and overhead costs.

BOOK REVIEWS

"Hydro - Electric Engineering." *By Geoffrey Gerard, F.R.S.E., A.M.I.E.E., 181 pp.—5½" x 8½". Sir Isaac Pitman and Sons Limited. Price 20 shillings.*

IF amateur hydro-electric engineers existed Mr. Gerard's book would suit them well. This is not meant to be an unkind observation on his work—to sum up (in a single text book of modest size) all aspects of a subject to which many learned engineers and scientists have devoted the whole of their lives is an achievement in itself; and the result has a definite value to those who are not directly and fully employed in the practice of hydro-electric engineering.

From the point of view of the specialist this book will have value in the assembly, in a convenient form, of a considerable amount of data which only exists piecemeal in other media. Mr. Gerard deals with every aspect — from general considerations of the world's hydro-electric resources to methods of assessing the power available from a given scheme; from civil engineering work to turbines, generators, transformers, and switchgear; and from commissioning of plant, operation and maintenance to brief general remarks about tidal power schemes.

When it is known that only 11½ pages (in which there are three line, three half-tone, and one cross-sectional diagram of an alternator) are devoted to the whole subject of alternating current generators for water turbines, it will be realized that he has attempted, and partially achieved, a miracle of compression: in the first five of these 11½ pages, he also gives a rapid exposition of alternating current theory.

It could, perhaps, be argued that a chapter of 21 pages on switchgear, in which again a succinct survey is attempted on both the first principles and the types of modern switchgear, is out of proportion to its value for the reader interested only in hydro-electric problems. Nevertheless, there may be many readers who will welcome Mr. Gerard's book. Students in other branches of engineering who wish to have on their shelves a short survey of hydro-electric practice will find it worth a large proportion of the 20 shillings it costs; the scientifically inclined laymen, who sometimes are elected to technical committees on unfamiliar subjects, will find the book worth at least double.

J.H.M.S.

OSBORNE REYNOLDS

By Professor A. H. Gibson, D.Sc., LL.D., M.Inst.C.E., M.I.Mech.E., 33 pp.—6¼" x 8⅝". Published for the British Council by Longmans Green & Co. Price 1/6.

THIS memoir, written appropriately by one of our leading hydraulic engineers about another eminent pioneer in this branch of science, is much more than a biography of the man whose name will never be forgotten as long as engineers use the "Reynolds Number," if for no other reason. That there are many other reasons is shown by the fascinating descriptions of Reynolds's work on tidal models; his researches into lubrication problems (the results of which had a far-reaching influence on practice in bearing design); and by his many papers which dealt with diverse aspects of hydro-dynamic research.

The mere numerical length of the list of papers by Reynolds reveals his great assiduity and energy; the range of subjects shows him to have been one of the outstanding research workers of his—or any other—generation.

J.H.M.S.

Power Generation in Japan

(We are indebted to the Assistant Economic Adviser of the United Kingdom Liaison in Japan for this information

HYDRO-ELECTRIC plant in Japan comprises 1,339 plants of a total rated output of 6,064,284 kW. The normal peak load is 4,004,344 kW, and the normal operation level of output is 2,644,342 kW.

Of these plants, the majority are small; only 267 have over 5,000 kW capacity. The *percentage* of hydro-electric to thermal power generation in Japan is high and it is increasing. In 1937 81 *per cent.* of Japan's power came from water power sources and 19 *per cent.* from steam power stations; the latest figures, which relate to 1947, show 97 *per cent.* hydro-electric and 3 *per cent.* steam power.

Three-quarters of the hydro-electric power plants in Japan are concentrated in the central Honshu area, since both the water power sources and the load due to the concentration of large cities in that area are more favourable to water power development than in any other part of Japan.

The more recent installations are of Japanese design and manufacture, and a typical scheme of the smaller kind comprises a division dam of masonry or concrete with gates controlling the flow of water into the intake. Desilting chambers are frequently provided before the water enters the conduit to the fore bay, and steel penstocks convey the water to the turbines. Troubles have appeared, apparently due to insufficient appreciation of friction losses, particularly in the pipe lines; while encrustation in the tunnels and conduits has been a source of reduced efficiency.

Storage capacity has been provided only in nine developments, but silting troubles have largely invalidated the advantages so gained. The dams in Japan have largely been limited in size due to the ever-present fear of earthquakes.

The total water power potential of Japan was last ascertained in 1923, and was then shown on the basis of mean flow as 10,150,000 kW. It is not thought that any factors which have come to light since that time have caused any material change in this figure. Much of the newly developed power, however, lies in isolated areas, and the economic possibilities of such developments are doubtful.

Regarding the management and ownership of electric power plants in Japan, it may be noted that during the war years a government-sponsored monopoly, the Nippon Hassoden K.K., was formed for the purpose of increasing production and raising efficiency. This corporation controls 76 *per cent.* of the hydro-electric power in Japan. Distribution is carried out by government-sponsored monopolies, which in certain cases own small hydro-electric plants of their own; there are a few companies also employed in this field. The chemical industry accounts for some 5 *per cent.* of the total output of hydro-electric power and there are 18 companies employing their own private generating plants.

The attempts at rehabilitation of Japanese industry have meant that more power has been needed, and there was a critical power shortage in the winter of 1947/48 with frequent breakdowns which reflected the dilapidated state of many of the power producing plants. There was, however, little war damage to hydro-electric installations in Japan, largely because of their scattered disposition, with large numbers of small plants situated in mountainous terrain where accurate bombing would have been difficult.

The Economic Stabilization Board announced in May of last year its first tentative plan for economic rehabilitation. In this document the five-year plan for electric power development sets the power output for 1953 at 37,920 million kW hours. Ninety-three additional hydro-electric developments are contemplated. The fulfilment of these plans, however, has been greatly hampered by shortages of both materials and funds.

Contractors' Notes

Joseph J. Armfield & Co. Ltd.—In order to facilitate developments in several directions, it has been found desirable to divide their two main lines of business. The manufacture of "Armfield" water turbines and all business connected with it, and the manufacture and installation of sluice gates for river control, will be carried on by the Armfield Hydraulic Engineering Co. Ltd., Christchurch Road, Ringwood, Hants. Joseph J. Armfield & Co. Ltd. will continue their business of agricultural and milling engineers, retaining their head office at 127, Christchurch Road, Ringwood, and their works at Stuckton Ironworks, Fordingbridge, Hants. Both companies are engaged on programmes of development in their respective spheres, and by concentrating upon them will be able to give better service than

had been possible before the division of interests.

John Blackwood Hodge and Company (London).—As British agents for the Marion Power Shovel Company of America, attention is called to the "world's largest shovel" which contains a 45 cubic yard load. This new dipper, the practicability of which has yet to be proved, was made possible by a complete re-design that stripped every possible pound of excess weight from the 40-yard dipper and its handle. It is interesting to note that the new 45 cubic yard dipper, fully loaded, weighs no more than the 35 cubic yard dippers (fully loaded) of three years ago. One substantial weight reduction was accomplished by substituting the armour plate steel for cast manganese in the construction of the dipper lip, a part that is subject to extreme wear.

Just two years ago "Marion" made war-developed modified armour plate steel into a 40 cubic yard dipper. Prior to that, a 35 cubic yard dipper had been the world's largest, and only by using the new stronger steel in lighter sections could the increase to 40 yard capacity be achieved. Since that time, nine of the big 40-yard dippers have been built and placed in service.

British Insulated Callender's Cables Limited.—A fault locating device, known as the "Bimec" Locator, is now in production. It overcomes the usual limitations of search coil methods which arise from re-radiation of the injected signal by neighbouring cables or adjacent iron work. No calculation is involved and efficacy of location is practically unaffected by the type of cable, the presence of armouring, or a change in cable section along the route. Nor is it necessary to know the length of the cable.

The locator is suitable for detection of short circuit faults on cables of all types, and for tracing unknown cable routes. During the past five years over 95% of the faults requiring location in a supply area having over 1,000 miles of underground mains have been found. The mains ranged from 0.25 sq. in. 33 kV, 3-core cables to 0.0045 sq. in. 1. v. twin service cables.

Dominion Engineering Company, Montreal, Canada.—During 1948 the installation was completed of the following hydraulic turbines:

12,000 h.p., 30 ft. head propeller turbines, Units 7 and 8 at Slave Falls Plant, Winnipeg.
55,000 h.p., 78 ft. head Francis turbine, the fourteenth Dominion turbine of this capacity in the Beauharnois Station of the Quebec Hydro.
27,500 h.p., 290 ft. head units; two for the Aguasabon Plant in Ontario.
65,000 h.p., 145 ft. head Francis turbines; three for the station at Shawinigan Falls, Quebec.
19,000 h.p., 56 ft. head propeller turbine unit for the Island Falls Plant of the Churchill River Power Company in Saskatchewan.

Shipment was completed during the year of the following additional turbines which are now being installed:

62,800 metric h.p., 32.5 m. head Francis Turbine for installation in Brazil.
16,000 h.p., 72 ft. head Francis turbine for plant of the Quebec Hydro on the upper Ottawa River.
28,000 h.p., 390 ft. head, Units 3 and 4 of the Campbell River Plant of the B.C. Power Commission.
4,600 h.p., 45 ft. head propeller turbine for the Montreal Engineering Company's Methols Plant in Nova Scotia.

Initial shipments were made and installation was started of the following units:

62,000 h.p., 130 ft. head Francis turbines; eight for the Des Joachims Plant of the Ontario Hydro-Electric Power Commission.
37,500 h.p., 66 ft. head propeller units Nos. 4 and 5 of the Seven Sisters Plant of the Winnipeg Electric Company.
27,000 h.p., 60 ft. head propeller unit of the Bryson plant of the Gatineau Power Company.
4,500 h.p., 185 ft. head Francis turbine for the Montreal Engineering Company's Black River Plant in Nova Scotia.

New orders were obtained during the year for the following additional turbines:

4,500 h.p. impulse unit for export to Bolivia.
62,000 h.p., 875 ft. head Francis turbine for the Spray Plant of Calgary Power Ltd.
37,000 h.p., 90 ft. head Francis type turbine for the Brilliant Plant of the Consolidated Smelters.
65,000 h.p., 159 ft. head Francis Units; five for the Trenche Plant of the Shawinigan Water and Power Company.
55,000 h.p., 78 ft. head units; three for the extension of the Beauharnois Station of Quebec Hydro on the St. Lawrence River near Montreal.
21,000 h.p., 40 ft. head propeller turbines; eight for the Chenaux Plant of the Ontario Hydro-Electric Power Commission.
19,000 h.p., 37 ft. head propeller units; six for the Pine Falls Plant of the Province of Manitoba.

All of these machines are scheduled for shipment before the end of 1951.

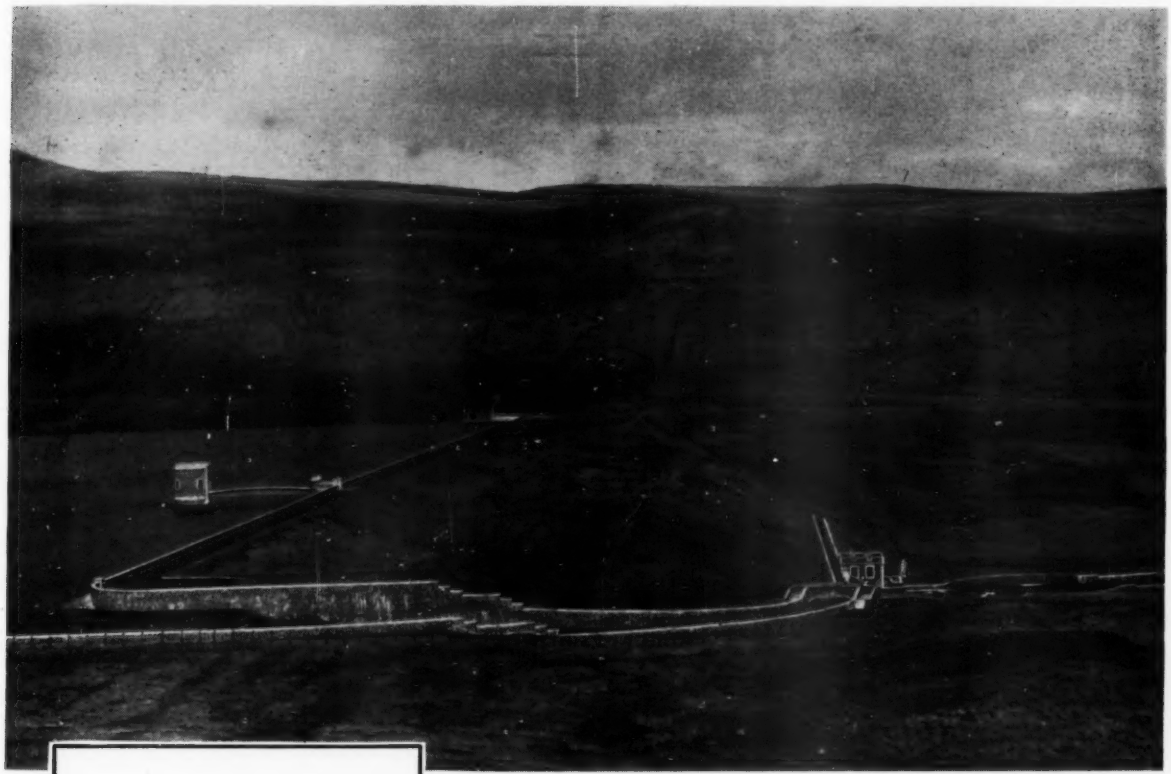
Gilbert Gilkes & Gordon Ltd., Kendal.—The North of Scotland Hydro-Electric Board, through their consulting engineers, Messrs. Merz and McLellan, Newcastle-on-Tyne, have ordered a 700 b.h.p. Turgo impulse wheel operating under a net head of 265 feet for the Errochty Dam compensation water in connection with the Tummel-Garry Scheme. This turbine will be provided with hand spear regulation for passing a constant flow of water and will be direct coupled to an induction generator. There is no governor but a hydraulically operated jet deflector gives protection against overspeed. Although the conditions were apparently favourable to a Francis type turbine, an impulse turbine was selected as for the major portion of the year the turbine will operate with less than 50% of the maximum flow of water and high part load efficiency it, therefore, a primary consideration.

Two small sets have also been ordered by the North of Scotland Hyro-Electric Board for extensions to their power station at Tobermory in the Island of Mull. These will consist of 250 kVA and 100 kVA Francis turbine driven sets to operate in parallel with existing and new oil engines. Remote water level control will be fitted so that the turbines will shed load to the oil engines in the event of the water level at the intake beginning to fall.

Through Metropolitan-Vickers, Manchester, an order has been received for a 2375 b.h.p. Francis turbine operating under a head of 40 metres for the Skeidsfoss Hydro Electric Scheme, Iceland.

Metropolitan-Vickers Electrical Company.—On Sunday, July 10, the 50th anniversary of the company, previously known as British Westinghouse Electric and Manufacturing Co., will be officially recognized. Special arrangements are being made to celebrate the jubilee, and between June 22 and July 9 the factory in Manchester will be open for the inspection of its most up-to-date conditions of post-war manufacture. Invitations are being extended to a limited number of the company's associates.

Whatever and wherever the project



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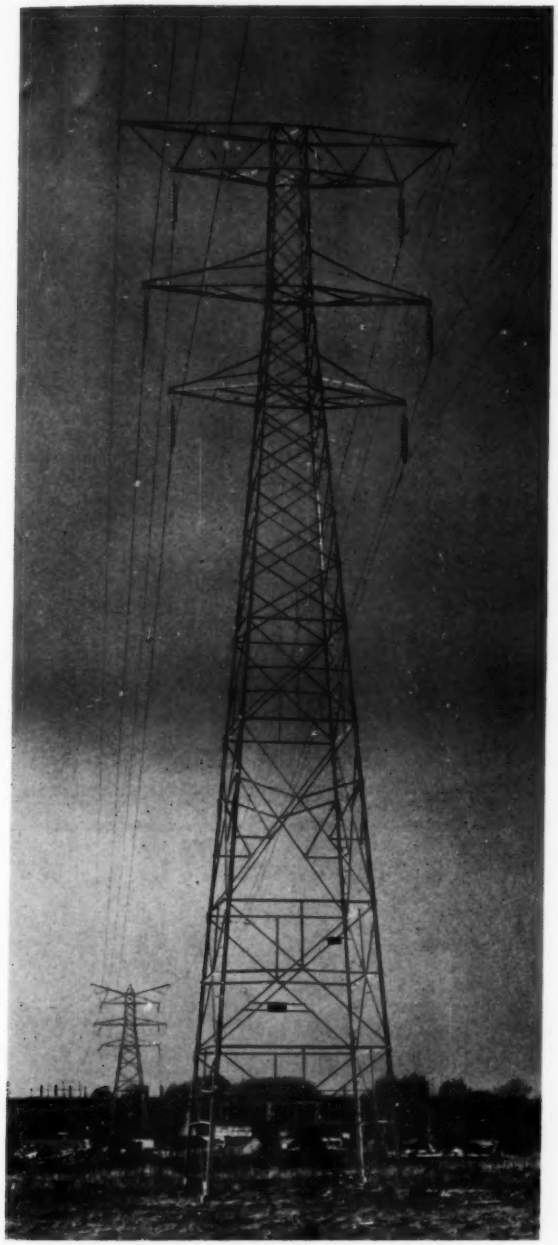

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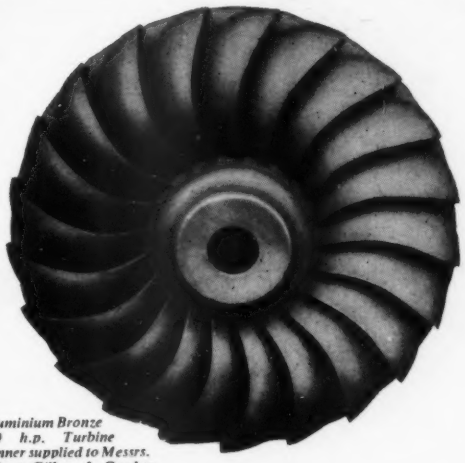

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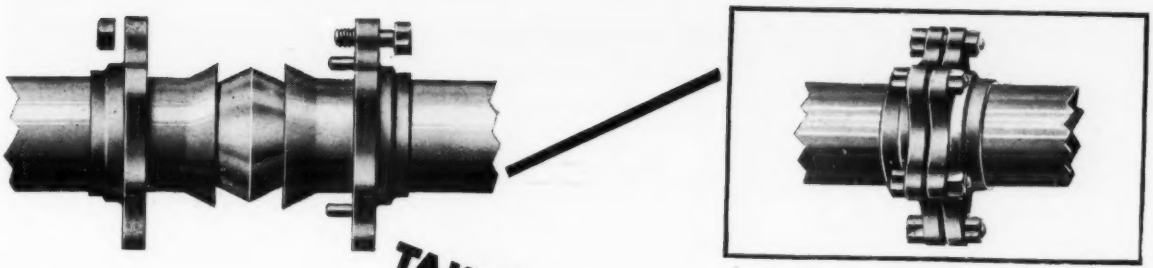

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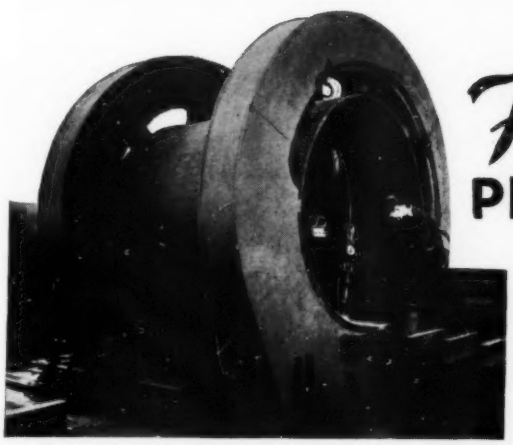

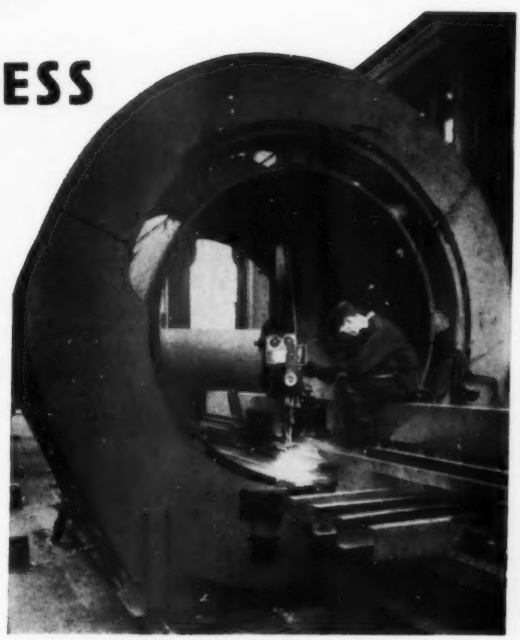

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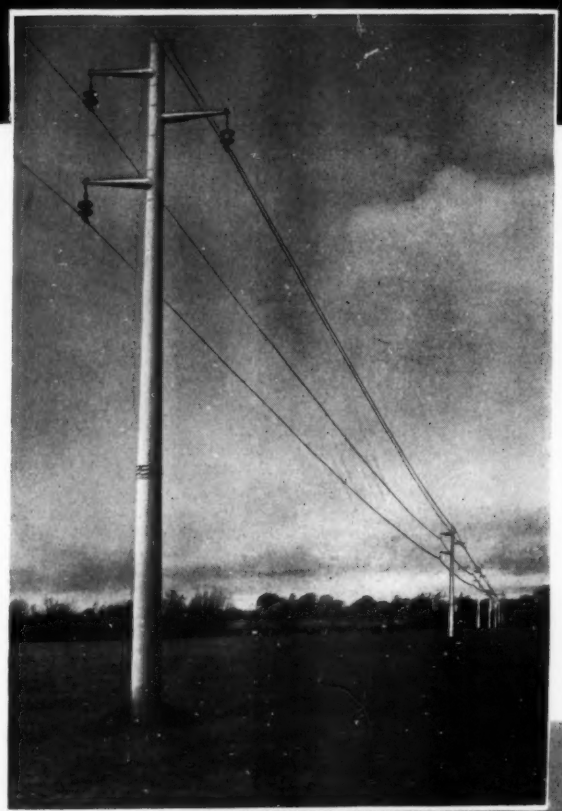

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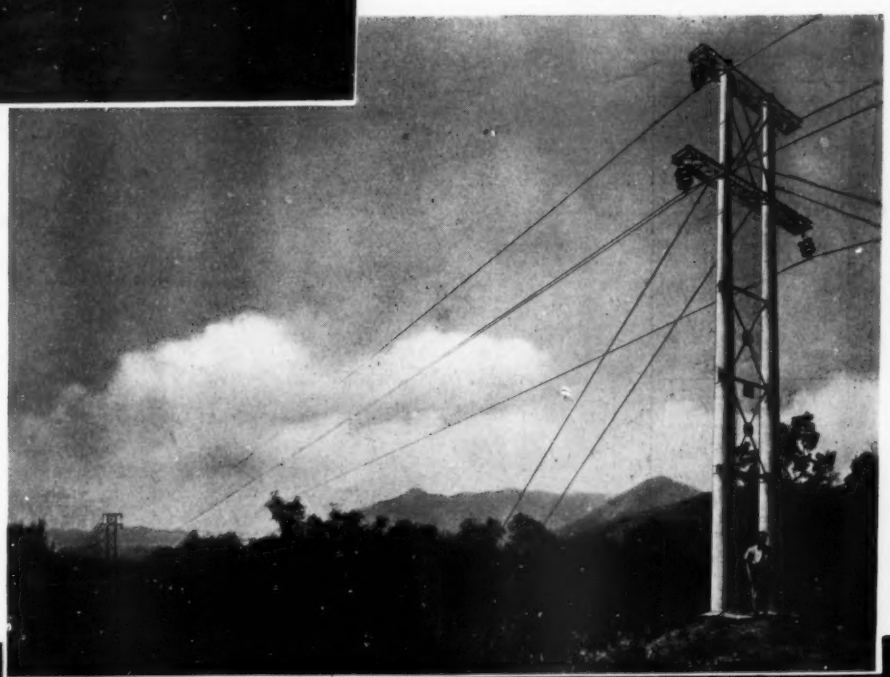

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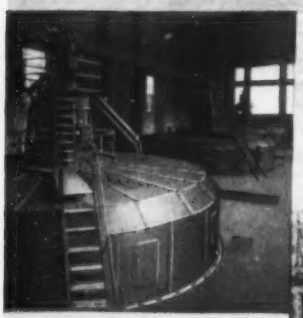

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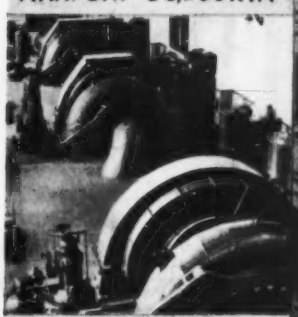

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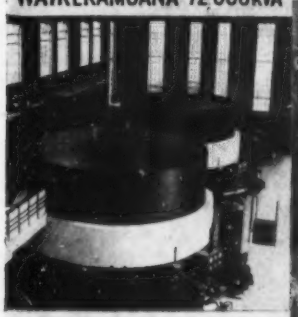

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